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PASSIVE VIBRATION CONTROL OF THICK ALUMINUM PLATES USING VISCOELASTIC LAYERED DAMPING

by

PING HSIN-CHIH

December, 1990

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PASSIVE VIBRATION CONTROL OF THICK ALUMINUM PLATES USING VISCOELASTIC LAYERED DAMPING

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ABSTRACT

This paper considers two constrained viscoelastic layer damping treatments applied to a thick aluminum plate; a milled pocket, and a milled floating element configurations. The effectiveness of the Modal Strain Energy (MSE) method was investigated for the constrained viscoelastic layer damping design. A comparison of experimentally measured modal loss factors and natural frequencies with those predicted by the modal strain energy method is presented.

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I. INTRODUCTION

A. BACKGROUND

Ship silencing is an important issue of modern naval warfare. For a long time, naval ship engineers have tried to reduce the noise from the vibration of shipboard components. This is important for a ship to accomplish its mission with good survivability. One method, called constrained viscoelastic layer method, uses shear deformation in viscoelastic material to absorb and dissipate the vibrational energy of the system. It shows promise in damping over a broad frequency spectrum of vibration.

A finite element technique developed by Johnson and Kienholz [Ref.1] known as the Modal Strain Energy (MSE) method which uses the ratio of strain energy for each mode shape to approximate the modal damping of a structure for a given constrained viscoelastic damping system. This method is very attractive due to its simple concept and very useful because it can be applied to any general cases with arbitrary shape by using the finite element method. Previous work by Bateman [Ref. 2] addressed the effectiveness of the MSE method for three damped plate configurations: 1) a single layer sandwich configuration, 2) a double layer sandwich configuration, and 3) a plate with a milled pocket with damping material inserted and a spot welded cover plate acting as a constrained layer. Difficulties with the welded cover plate is that during welding, the cover plate can be warped and delaminated itself from the damping material, resulting in negligible damping [Ref. 3].

B. PURPOSE

Development of the model enhancing the vibration damping, reducing the noise and vibration is the main purpose. This paper will concentrate the experimental testing and analysis of two configurations of aluminum plates: 1) milled pocket plate, a plate with a milled pocket with damping material inserted and a welded cover plate acting as a constraining layer. and 2) floating element plate, like pocket plate but between welded cover plate and milled pocket inserted a floating element that was a thin aluminum plate with two damping material on upper and lower sides. The floating element was made slightly smaller than the surrounding structure thus allowing the floating element to act as a "true" constraining layer. Each plates expose to three different temperatures, 4.44 °C (40 °F), 15.6 °C (60 °F), 26.7 °C (80 °F) to simulate different environment.

The MSE method is used to analyze and predict each of the structures, and compare to experimental results. Its accuracy and usefulness as a possible design tool are investigated.

C. PLATE CONFIGURATIONS

The dimensions of the pocket plate are : base plate 114.30 cm (45 in) in length and 38.1 cm (15 in) in width,viscoelasic material 111.13 cm (43.75 in) in length, 34.93 cm (13.75 in) in width, and 0.038 cm (0.015 in) in thickness, cover plate 113.03 cm (44.5 in) in length, 36.83 cm (14.5 in) in width, and 0.635 cm (0.25 in) in thickness. The total thickness is approximately 1.91 cm (0.75 in).

The dimensions of the floating element plate are: base plate 114.30 (45 in) cm in length and 38.1 (15 in) cm in width, two viscoelasic material 111.13 cm (43.75 in) in length, 34.93 cm (43.75 in) in width, and 0.038 cm (0.015 in) in thickness, the aluminum plate between two viscoelastic material 111.13 cm (43.75 in) in length, 34.93 cm (13.75 in) in width, and 0.3175 cm (0.125 in) in thickness, cover plate 113.03 cm (44.5 in) in length, 36.83 cm (14.5 in) in width, and 0.381 cm (0.015 in) in thickness. The total thickness is approximately 1.91 cm (0.75 in).

The aluminum plate is a standard 6061-T6 aluminum alloy and the viscoelastic material is a polymeric compounds from 3M company type ISD-112.

The details of two plate configurations are shown in Appendix A.

II. THEORY

A. MODAL STRAIN ENERGY METHOD

The equations of motion for the discretized continuous system can be expressed in the following form:

$$[M]\{\ddot{x}(t)\} + [C]\{\dot{x}(t)\} + [K]\{x(t)\} = \{F(t)\} \tag{2-1}$$

where,

[M] = Mass matrix

[C] = Damping matrix

[K] = Stiffness matrix

Introducing linear transformation from physical coordinate system, $\{x(t)\}$ to modal coordinate system, $\{q(t)\}$, into the equation (2-1),

$$\{\ddot{q}(t)\} + [\eta_i \omega_i]\{\dot{q}(t)\} + [\omega_i^2]\{q(t)\} = \{F(t)\} \tag{2-2}$$

$$\{x(t)\} + [\Phi]\{q(t)\} \tag{2-3}$$

$$\{f(t)\} = [\Phi]^T\{F(t)\} \tag{2-4}$$

where $[\eta_i \omega_i]$ and $[\omega_i^2]$ are diagonal matrices. Equation (2-2) is decoupled equations of motion in modal space.

For MSE method, the i-th modal loss factor, η_i in equation (2-2) can be approximated by the following expression,

$$\eta_i = \eta_{v:\,i}\left(\frac{V_{v:\,i}}{V_{T:\,i}}\right) \tag{2-5}$$

where

η_i = i-th modal loss factor

$\eta_{v:\,i}$ = viscoelastic material loss factor at i-th modal frequency

$V_{v:\,i}$ = elastic strain energy in viscoelastic layer at i-th modal frequency

$V_{T:\,i}$ = total strain energy at i-th modal frequency

For this method, modal analysis was used to calculate the fraction of elastic strain energy in the viscoelastic material at each corresponding mode and to calculate modal loss factor defined in equation (2-5).

Because the natural frequency depends on material properties, an iterated solution of the eigenvalue problem for each mode and the material vs. frequency relation is required.

A simple empirical correction allows an approximate correction for frequency-dependent material properties [Ref. 4]. The modal damping ratios are adjusted according to

$$\eta_c^{(r)} = \eta^{(r)}\sqrt{\frac{G_2(f_r)}{G_{2,ref}}} \tag{2-6}$$

where,

$\eta_c^{(r)}$ = corrected modal loss factor at the r^{th} mode

$G_2(f_r)$ = viscoelastic shear modulus at the r^{th} modal frequency

$G_{2,ref}$ = reference viscoelasitc shear modulus used in the frequency response calculation

calculation to obtain modal frequency, mode shape, and masses

$G_{2,i}$ = viscoelastic material shear modulus at f = fi where fi is the i-th natural frequency of the i-th mode calculated with $G = G_{2,i,ref}$

In using Modal Strain Energy Method the MSC/NASTRAN code [Ref. 5] was used to estimate the natural frequency, mode shape, and strain energy.

B. VISCOELASTIC MATERIAL

The long molecular chains of most elastomeric or rubberlike materials have much higher level of damping than is the case of metals. The behavior is usually linear for low strain levels and nonlinear for high, as well as being frequency and temperature dependent.

Viscoelastic material is one kind of elastomeric material. In this paper we use 3M company ISD-112 viscoelastic material as damping treatment material. The advantage of the viscoelastic material is its ability to dissipate vibrational energy as heat through the streatching and relaxation of long polymeric moleculus chains [Ref. 6]. The change of the modulus will affect the damping capability of the material. Thus, the viscoelastic material properties, such as shear modulus and modal loss factor, will vary depending on the temperature and frequency.

The properties of 3M ISD-112 viscoelastic material usually display as a "reduced frequency nomogram." The reduced frequency normogram display the viscoelastic material's loss factor and shear modulus varying with temperature and frequency. The reduced frequency normogram for 3M ISD-112 is shown in Figure 2.1. To find the loss factor and shear modulus using the nomogram first we should know the temperature and the corresponding frequency then go into the normogram with temperature diaganally down the page and frequency horizontally to the left until the two lines intersect. Then from the intersect point going up or down to intersect the loss factor or shear modulus curve . Reading the intersect point we can get the loss factor or shear modulus horizontally from the scale from the left [Ref. 8].

C. CONSTRAIN VISCOELACTIC DAMPING

Constrained viscoelastic layer damping treatment is one of the most efficent ways of introducing damping into a structure. Pocket plate And floating element are two new configurations of this treatment. The component of those plates are standard 6061-T6 aluminum alloy plate and 3M ISD-112 viscoelastic material as damping material.

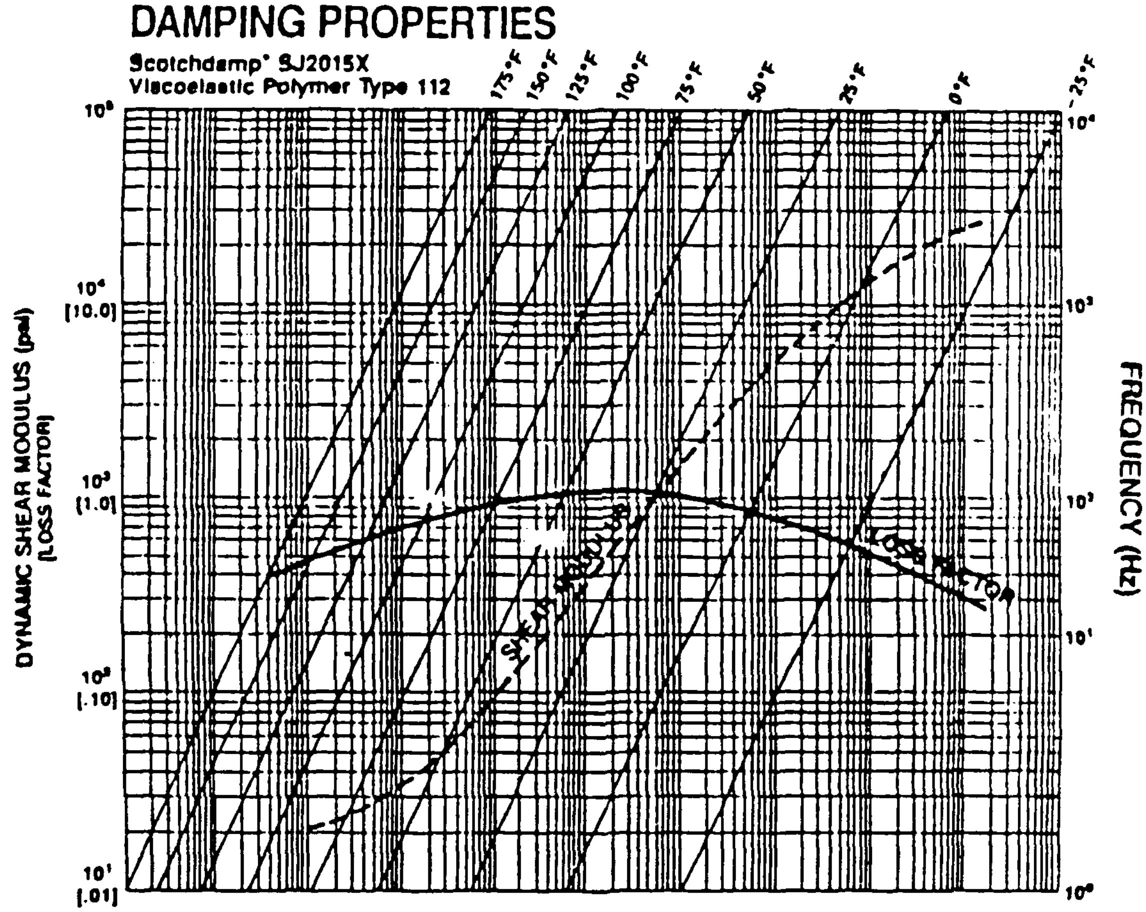

Figure 2.1. Reduced Frequency Normogram for 3M ISD-112 [Ref. 6].

III. EXPERIMENT

A. TESTING ARRANGEMENT

Experimental testing was performed on each of the two damping configurations and an undamped reference plate. In order to approximate the free-free boundary condition, each plate was suspended from the roof of the testing chamber using elastic cords as shown in Figure 3.1. All the tests were performed in a temperature controlled environmental chamber which enabled temperatures to be maintained within ±0.5 °C. The primary component and user interface was the Hewlett-Packard (HP) 3562A Dynamic Signal Analyzer (DSA). The HP-3562A was used to provide a swept sine signal to a vibration generator, and to analyze the returning data signals from the shaker and accelerometer. In addition, the HP-3562A computed the frequency response and coherence over a range of 40 Hz to 1040 Hz using the discrete Fourier Transform in the swept sine mode. Ten data were taken and averaged at each data point using a frequency resolution of 2.5 Hz per point. The source level output to the vibration generator was set at 1.5 volts.

The testing set up is shown in Figure 3.2. Swept sine linear sweep source signal were fed from the output jack of the HP-3562A to a Wilcoxon F3 vibration generator via the piezoelectric output of a Wilcoxon PA7C power amplifier. The vibration generator was mounted 73.48 cm (28.93 in) from one end, and 12.7 cm (5.0 in) from the front edge of each specimen as shown in

Figure 3.3. An integral force transducer was mounted in the base of the vibration generator to measure the force input to the plate. This force signal was then fed to input channel one of the DSA via a PCB 462-A charge amplifier. Plate accelerations were recorded at various points using a PCB 303A-03 accelerometer as shown in Figure 3.3. Acceleration data were fed to input channel two of the DSA via a PCB 480D06 power unit and a PCB 482A05 power supply. Frequency response and coherence data was then recorded on disk for further analysis.

Temperatures inside the testing chamber were maintained using a NESLAB RTE-8 refrigerated circulating bath which pumped fluid through a small heat exchanger in the testing chamber as shown in Figure 3.2. In order to accurately monitor the temperature of the plates, a small thermocouple was inserted in the base of each plate.

B. TESTING PROCEDURE

1. Undamped Peference Plate

An undamped, reference, frequency response measurement was made at a temperature of 15.6 °C (60 °F) to set a standard response as a reference to compare the effectiveness with the damping treated plates. The undamped frequency response was recorded over a frequency range of 40-1040 Hz using a resolution of 2.5 Hz per point in the DSA. It does not depend on temperature.

2. Damped Plate Measurements

Frequency response measurements of the damped plates were made at three temperatures of 4.44 °C (40 °F), 15.6 °C (60 °F), and 26.7 °C (80 °F) at several nodes on the plates in order to get the damped response of as many modes as possible. The frequency response plots shown in this reports wewe taken at the location "1" indicated in Figure 3.3, unless otherwise noted. The locations of these nodes are shown in Figure 3.3. Responses were recorded over a frequency range of 40-1040 Hz with a resolution of 2.5 Hz per point in the DSA. Zoom measurements were also made to capture better data for certain modes. Modal loss factors were then estimated from the frequency response and coherence measurements using a curve-fitting technique described in reference [Ref. 10]. The curve fitting data were obtained from the DSA. The modal loss factors were averaged from the six measured nodes.

C. POCKET PLATE RESULTS

The cover for the milled pocket plate was secured in two ways: spot welded and continuous line welded. For the spot welded pocket plate, the weld configuration is shown in Figure 3.4. The continuous line weld was performed using a MILLERMATIC 200 welding machine. The machine has a constant potential DC arc welding power source and wire control/feeder system. It was carefully welded not to significantly raise the temperature around the welded area and not to damage the viscoelastic layer. They were tested at 4.44 °C (40 °F), 15.6 °C (60 °F), and 26.7 °C (80 °F) so that the effects of temperature on the damping treatment could be determined. From the test we will examine the effects of the heat on the viscoelastic material from welding.

1. Spot Welded Pocket Plate Results

Three plots of frequency responses of spot welded pocket plate at three different temperatures are shown in Figures 3.5 through 3.7. Comparison with the responses of the reference plate shows good damping and the viscoelastic layer was not damaged by welding. Due to the closely coupling of modes, loss factors for all modes were not measured. The frequency response of the damped plate is characterized by a frequency shift to the left and a reducing and smoothing of the frequency response compare to the undamped reference plate. The spot welded pocket plate was also effective at reducing the amplitude of the response peaks over the entire spectrum of treatment. The response curve became more rounded and the effects of the damping layer are seen as frequency increases. The modal loss factors for the spot welded pocket plate of three different temperature are listed in Table 3.1 and are plotted in Figure 3.8. The effect of temperature on the damping was obvious as shown in Figure 3.9. The results show the trend of increased damping with temperature decrease, and a corresponding shift of modal frequencies to the right as the viscoelastic material become stiffer in this temperature range. At lower testing temperature the viscoelastic layer become stiffer and damping levels were increased. The modal coupling will increase the modal loss factor values at frequency above 780 Hz. Hence, the measured modal loss factors in this range are not reliable.

TABLE 3.1. MEASURED MODAL LOSS FACTORS FOR THE SPOT WELDED POCKET PLATE AT 4.44/15.6/26.7 °C.

4.44 °C (40 °F)		15.6 °C (60 °F)		26.7 °C (80 °F)	
f (Hz)	η	f (Hz)	η	f (Hz)	η
64.6	0.094	62.1	0.067	60.0	0.044
95.9	0.076	93.4	0.042	91.1	0.025
146.9	0.092	142.0	0.056	138.2	0.031
200.9	0.088	194.9	0.060	187.9	0.035
319.0	0.079	308.9	0.051	299.4	0.040
446.1	0.059	437.5	0.041	424.8	0.032
576.8	0.067	495.6	0.036	445.1	0.043
642.4	0.072	565.3	0.043	547.7	0.034
711.5	0.076	625.7	0.047	613.0	0.048
857.0	0.054	643.2	0.049	633.5	0.042
		687.0	0.044	677.1	0.057
		841.9	0.056	829.2	0.038
		891.5	0.077		
		923.0	0.090		

2. Line Welded Pocket Plate Results

The effects of temperature on the continuous welded pocket plate were also investigated. Three plots of frequency response compared with the undamped reference plate at three different temperature are shown in Figures 3.10 through 3.12. From the figure it shows good damping, indicating the viscoelastic layer was not damaged by the heat of welding. The measured modal loss factor for the line welded pocket plate of three different temperatures are listed in Table 3.2 and are shown in Figure 3.13. The trend of increasing damping with decreasing temperature and shift of corresponding modal frequency to the left were similar to the spot welded pocket plate. The effect of temperature on the damping of line weld pocket plate was shown in Figure 3.14. Comparison of spot and line welded pocket plate at 4.44 °C (40 °F), 15.6 °C (60 °F), and 26.7 °C (80 °F) are shown in Figures 3.15 through 3.17. As can be seen in these figures, we the spot welded pocket plate has more damping effect than line welded one and the corresponding modal frequency shift to the left. The reason is line welded pocket plate is more constrained than the spot welded. Therefore, the cover plate of line welded pocket plate cannot induce shear deformation in the viscoelastic layer as well as spot welded pocket plate, and produce less damping than the spot welded pocket plate.

TABLE 3.2. MEASURED MODAL LOSS FACTORS FOR THE LINE WELDED POCKET PLATE AT 4.44/15.6/26.7 °C

4.44 °C (60 °F)		15.6 °C (60 °F)		26.7 °C (80 °F)	
f (Hz)	n	f (Hz)	n	f (Hz)	n
71.4	0.038	70.1	0.030	69.7	0.018
125.8	0.042	122.4	0.058	120.8	0.028
170.0	0.020	168.3	0.013	167.5	0.011
245.8	0.047	238.4	0.034	235.4	0.019
305.1	0.027	368.6	0.031	363.1	0.020
377.5	0.037	469.1	0.042	463.0	0.054
526.4	0.042	634.5	0.025	627.1	0.019
640.2	0.031	670.8	0.042	667.7	0.056
680.3	0.041	713.9	0.030	708.7	0.041
720.8	0.039	775.2	0.036	765.2	0.045
790.1	0.034	915.4	0.033	906.4	0.039
923.0	0.030				

D. FLOATING ELEMENT PLATE RESULTS

The milled floating element plate configuration was welded in two cases as for the pocket plate. The floating element was made slightly smaller than the surrounding structure thus allowing the floating element to act as a "true" constrain layer. That makes the viscoelastic layer have more space to shear. It thus have more shear deformation than the pocket plate and the modal loss factor will theoretically be higher than the pocket plate cases.

1. Spot Welded Floating Element Plate Results

Three plots of frequency response for the spot welded floating element plate are shown in Figures 3.18 through 3.20. Comparison with the reference undamped plate shows good damping. The spot weld floating element plate is very effective as the response shows a good reduction in peak modal response. Measured modal loss factors for three temperatures are listed in Table 3.3 and are shown in Figure 3.21. From the figures we found that the frequency response of the floating element configuration is characterized by a frequency shift to the left and a smoothing of the response as frequency increases. This trend is similar to the previous pocket plate cases. The effect of temperature on damping is quite clearly as shown in Figure 3.22.

TABLE 3.3. MEASURED MODAL LOSS FACTORS FOR THE SPOT WELDED FLOATING ELEMENT PLATE AT 4.44/15.6/26.7 °C.

4.44 °C (60 °F)		15.6 °C (60 °F)		26.7 °C (80 °F)	
f (Hz)	n	f (Hz)	n	f (Hz)	n
66.6	0.075	66.0	0.089	62.6	0.053
108.7	0.057	104.9	0.040	103.3	0.038
163.1	0.112	154.0	0.094	148.6	0.056
216.9	0.092	211.4	0.058	205.0	0.059
299.5	0.170	272.8	0.063	268.4	0.036
334.0	0.091	323.5	0.075	316.0	0.060
443.7	0.113	435.8	0.090	424.8	0.067
453.7	0.070	508.1	0.089	481.6	0.070
524.4	0.090	540.6	0.115	558.7	0.084
579.9	0.120	618.7	0.121	608.2	0.098
628.9	0.167	656.7	0.100	633.3	0.103
664.3	0.130	708.6	0.088	685.0	0.132
711.7	0.120	857.6	0.089	828.1	0.126
865.9	0.100	935.4	0.064	854.2	0.083
896.7	0.100			893.4	0.102

2. Line Welded Floating Element Plate Results

Plots of frequency responses for the line welded floating element plate at three different temperatures are shown in Figure 3.23 through 3.25. Comparison with the undamped reference plate shows good damping effect. The frequency response of the damped plate is the same with the previous cases. The measured modal loss factors for the line welded floating element plate of three different temperatures are listed in Table 3.4 and are plotted in Figure 3.26. The temperature effects are clearly evident as shown in Figure 3.27. Comparisons of frequency responses of the spot and line welded floating element plate at three temperatures are shown in Figures 3.28 through 3.30. Again, the figures show that spot welded floating element has better damping effect because it allows more shear deformation than the line welded one. The peaks are smooth along the whole range. Comparisons of spot welded pocket plate and floating element plate are shown in Figures 3.31 through 3.33. The other comparisons of line welded pocket plate and floating element plate are shown in Figures 3.34 through Figure 3.36. From these comparisons it is clear that the floating element plate has better damping than the pocket plate. The curves of frequency response are more smooth and the rounded peaks are shifted to the left. Reasons for this are the added constraining effect of the floating element and additional layer of damping material present.

TABLE 3.4. MEASURED MODAL LOSS FACTORS FOR THE LINE WELDED FLOATING ELEMENT PLATE AT 4.44/15.6/26.7 °C.

4.44 °C (60 °F)		15.6 °C (60 °F)		26.7 °C (80 °F)	
f (Hz)	η	f (Hz)	η	f (Hz)	η
73.1	0.043	71.3	0.039	70.3	0.029
126.8	0.063	124.7	0.040	124.7	0.022
175.7	0.055	171.7	0.035	169.8	0.024
254.0	0.045	248.6	0.033	246.3	0.021
381.8	0.080	368.8	0.168	394.0	0.109
486.7	0.080	476.1	0.062	471.6	0.061
525.7	0.063	516.4	0.101	512.4	0.086
537.8	0.130	653.5	0.096	647.2	0.093
674.1	0.104	731.1	0.081	717.3	0.078
748.0	0.083				
848.0	0.133				

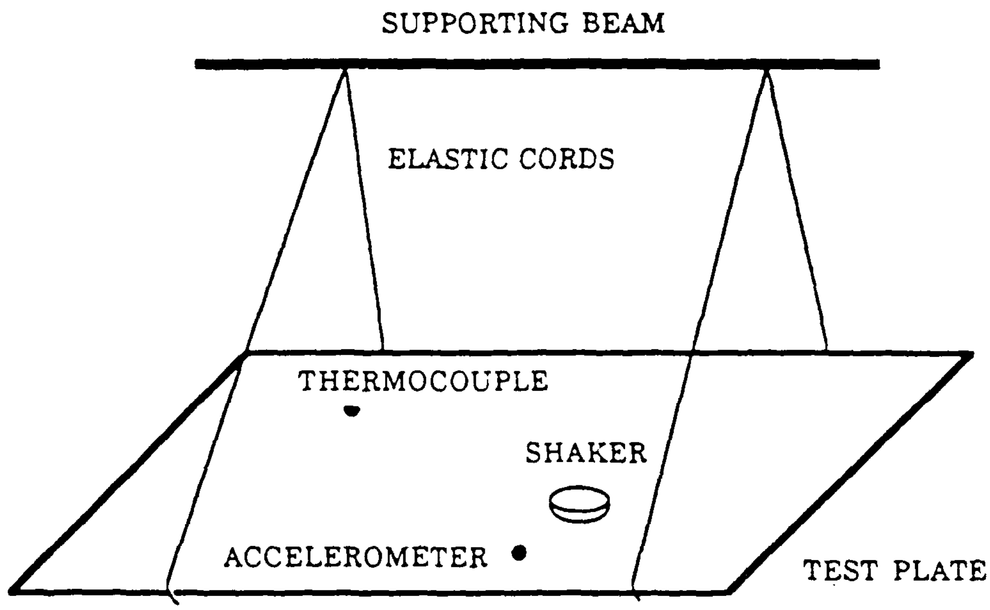

Figure 3.1. Testing Configuration In Testing Chamber.

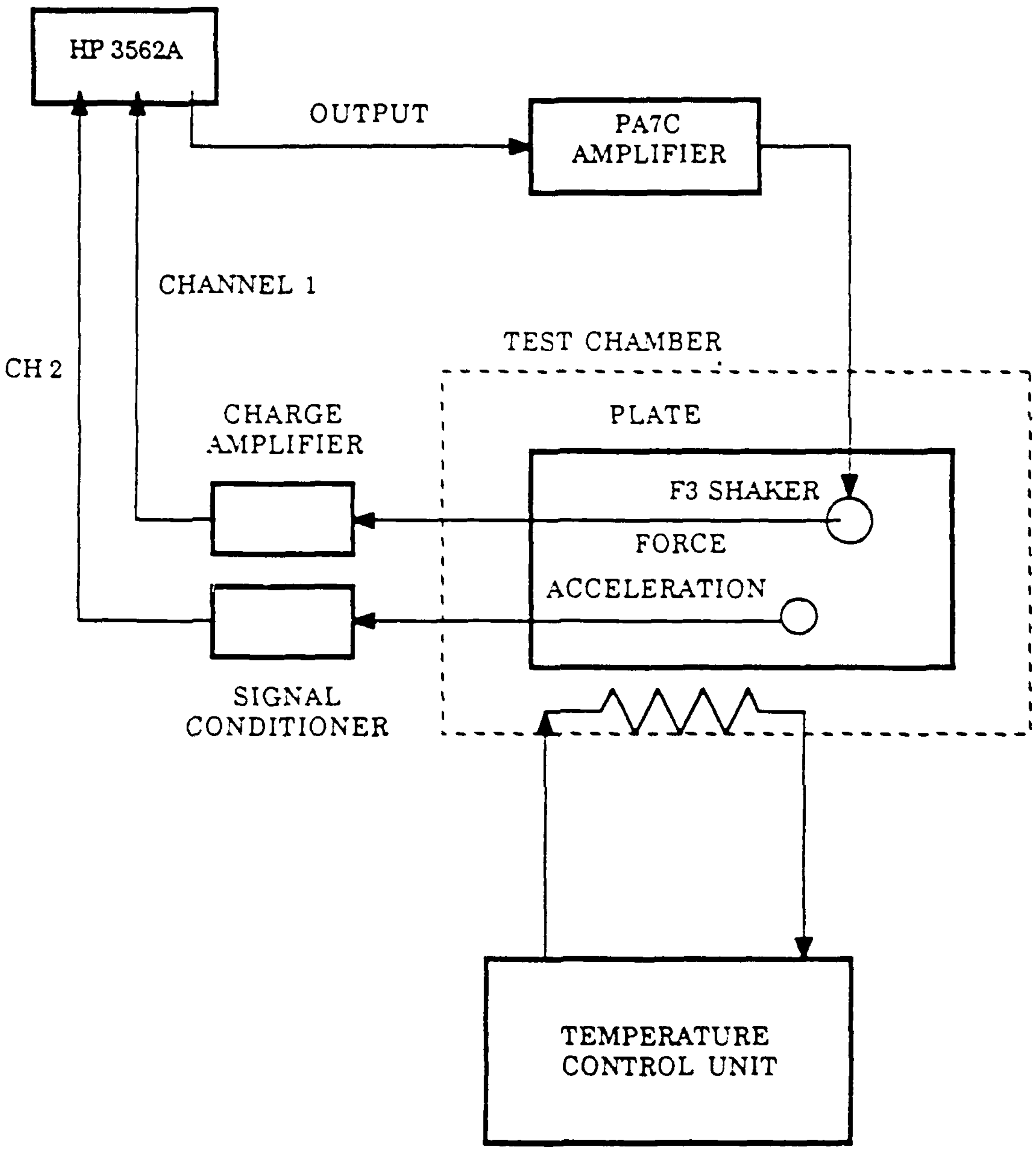

Figure 3.2. Schematic Diagram of Testing System.

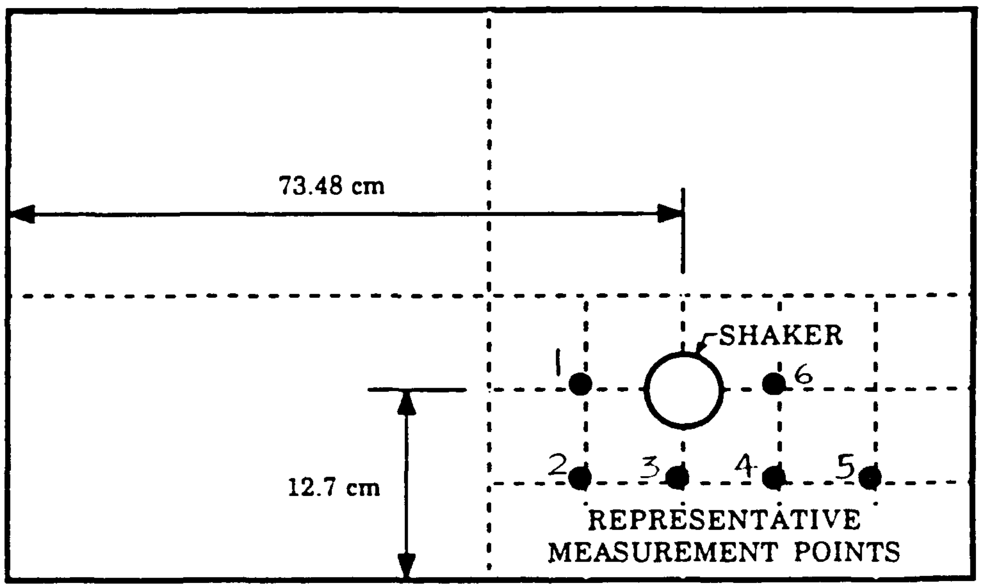

Figure 3.3. Shaker and Accelerometer Location.

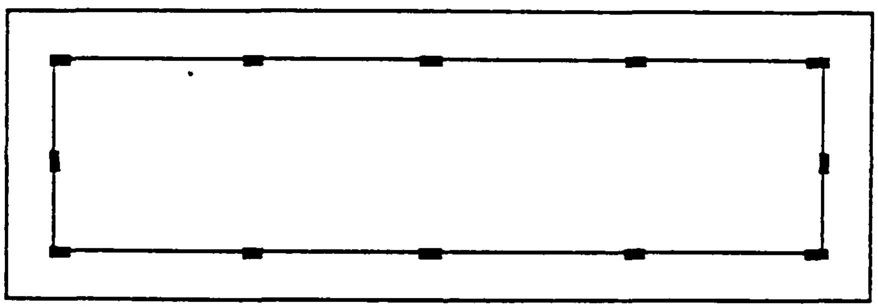

Figure 3.4. Location of Spot Welds on the Cover plate of Pocket Plat Configuration.

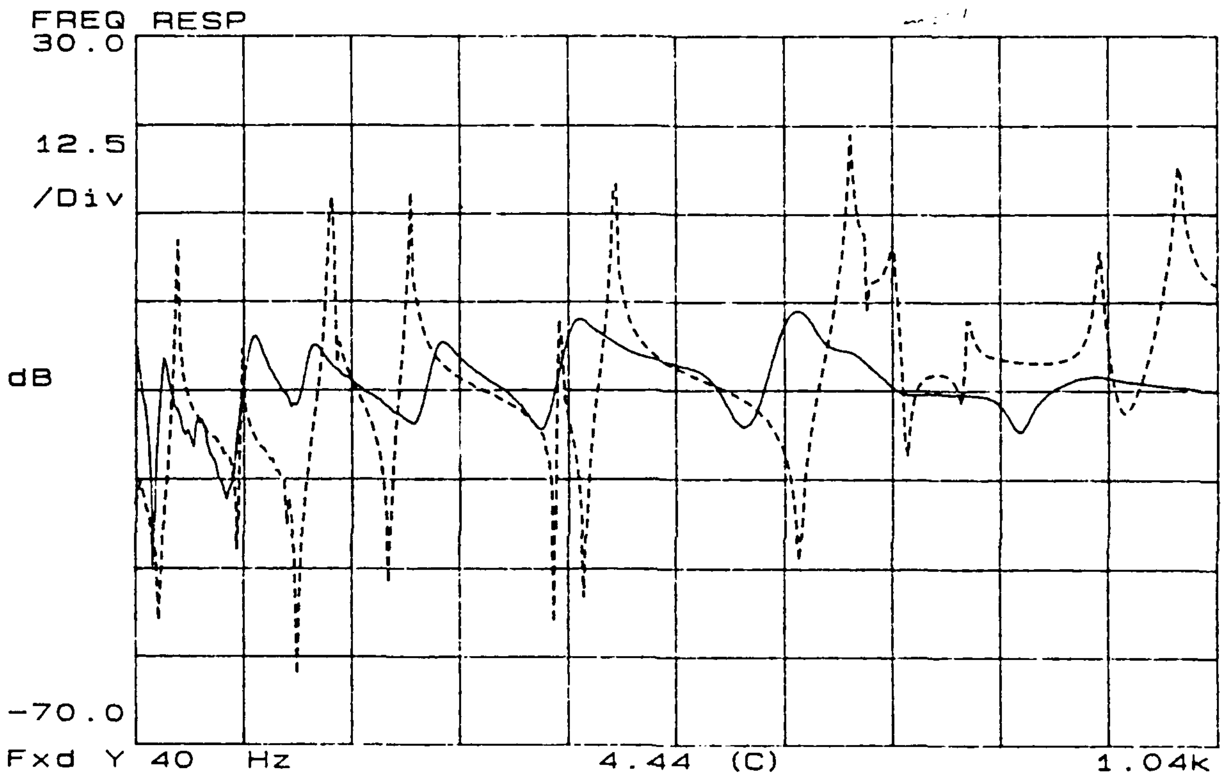

Figure 3.5. Measured Frequency Response of the Spot Welded Pocket Plate Configuration at 4.44 °C.

[- - - - : undamped response; ——— : damped response]

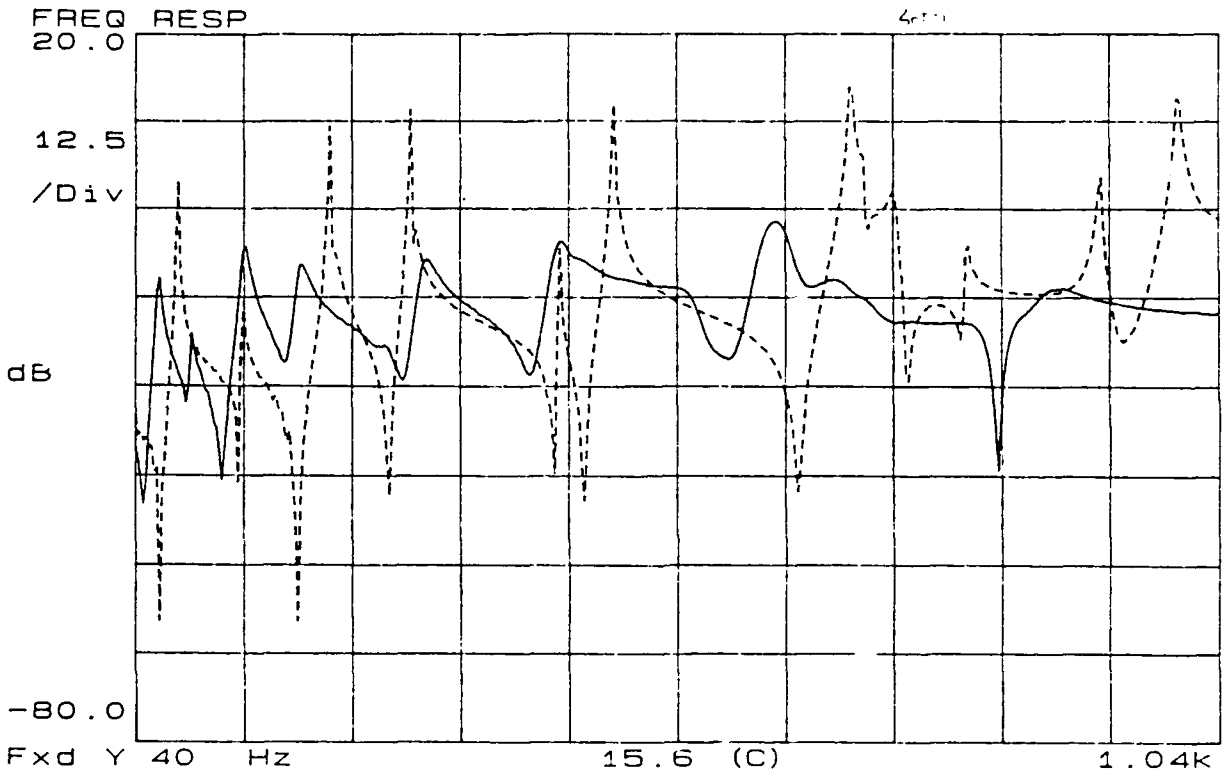

Figure 3.6. Measured Frequency Response of the Spot Welded Pocket Plate Configuration at 15.6 °C.

[- - - - : undamped response; ——— : damped response]

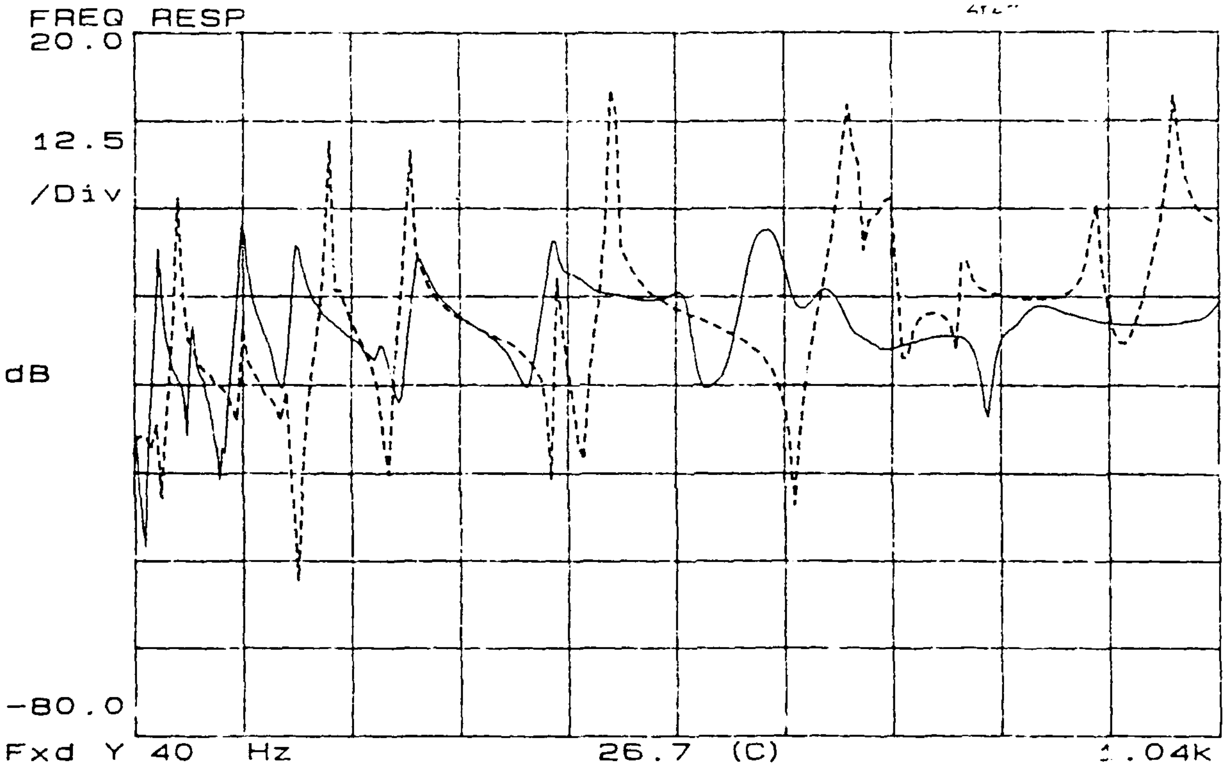

Figure 3.7. Measured Frequency Response of the Spot Welded Pocket Plate Configuration at 26.7 °C.

[- - - - : undamped response; ——— : damped response]

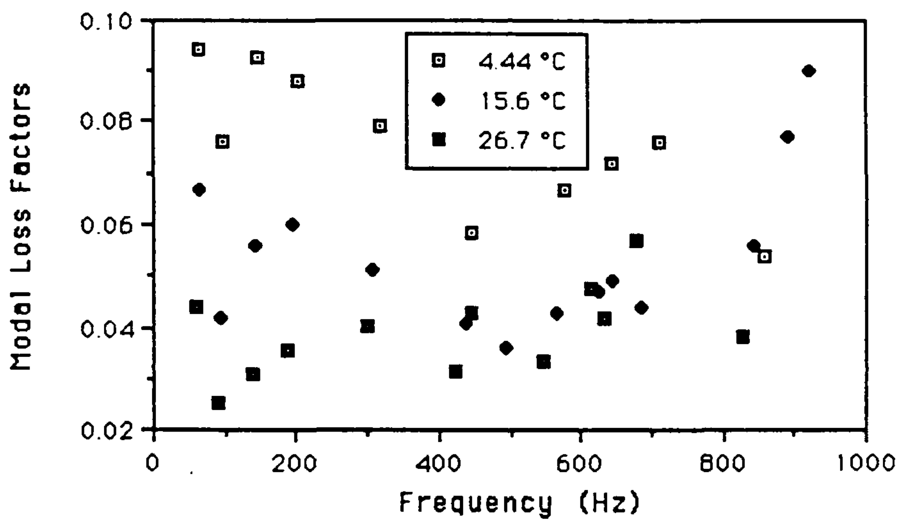

Figure 3.8. Measured Modal Loss Factor for the Spot Welded Pocket Plate at 4.44/15.6/26.7 °C.

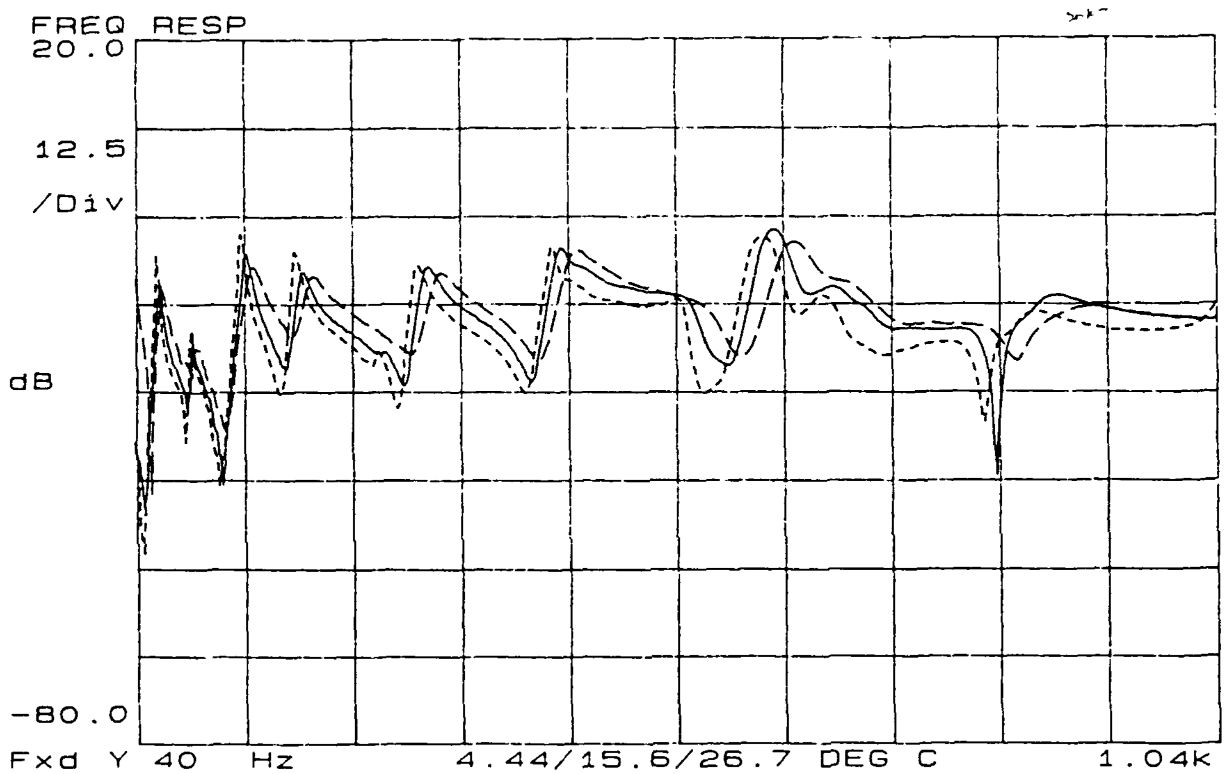

Figure 3.9. Measured Frequency Response of the Spot Welded Pocket Plate Configuration at 4.44/15.6/26.7 °C.

[— — —: 4.44 °C, ———: 15.6 °C, - - - -: 26.7°C]

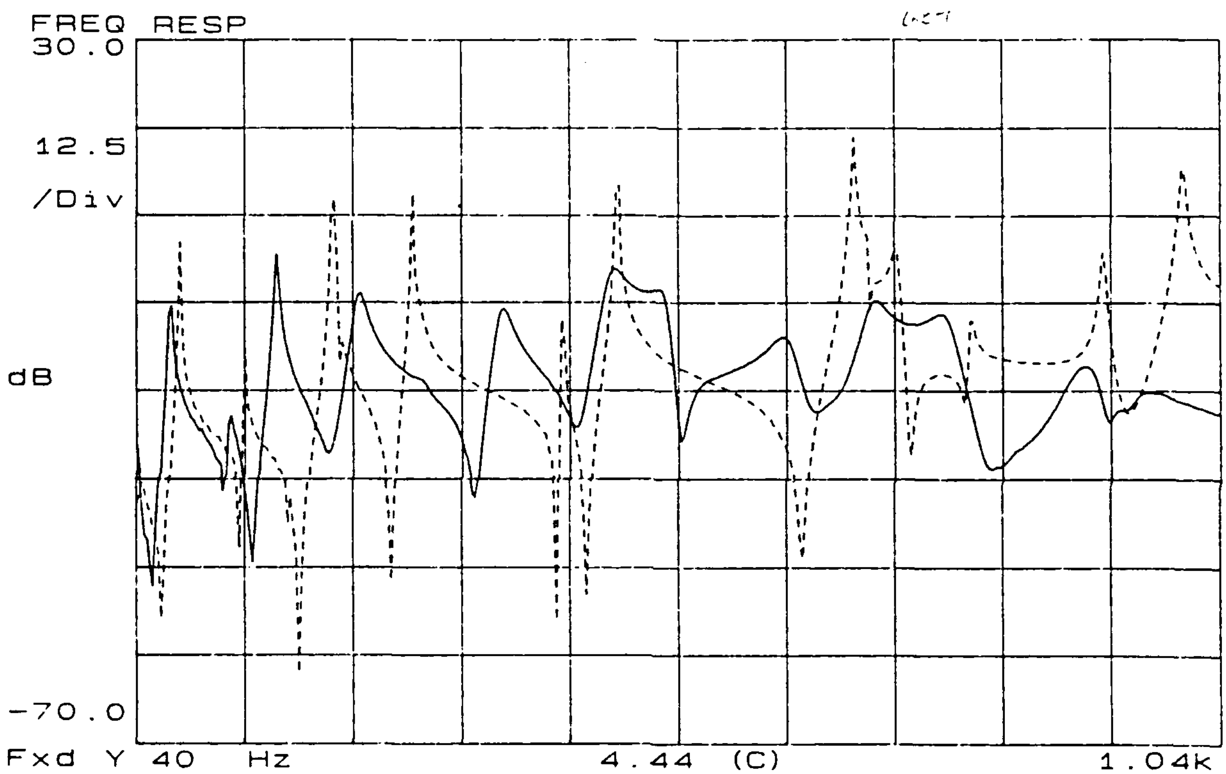

Figure 3.10. Measured Frequency Response of the Line Welded Pocket Plate Configuration at 4.44 °C

[- - - - : undamped response; ——— : damped response]

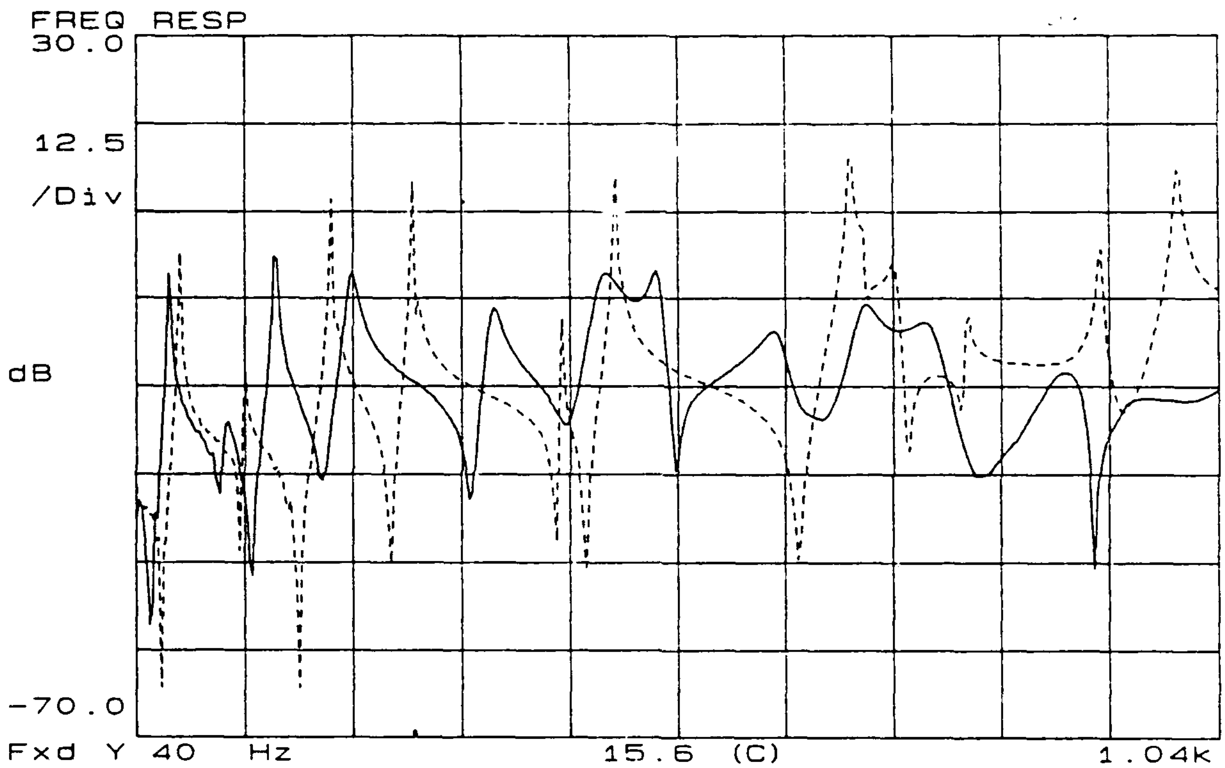

Figure 3.11. Measured Frequency Response of the Line Welded Pocket Plate Configuration at 15.6 °C.

[- - - - : undamped response; ——— : damped response]

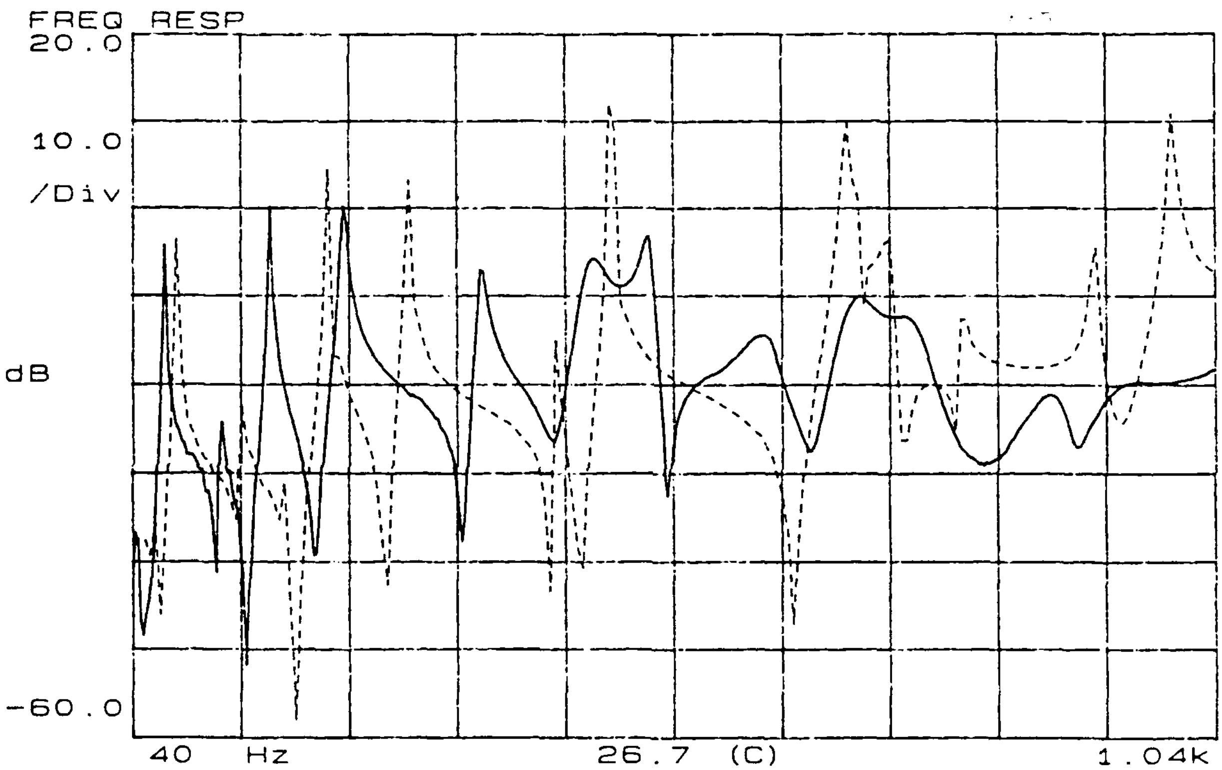

Figure 3.12. Measured Frequency Response of the Line Welded Pocket Plate Configuration at 26.7 °C.

[- - - - : undamped response; ——— : damped response]

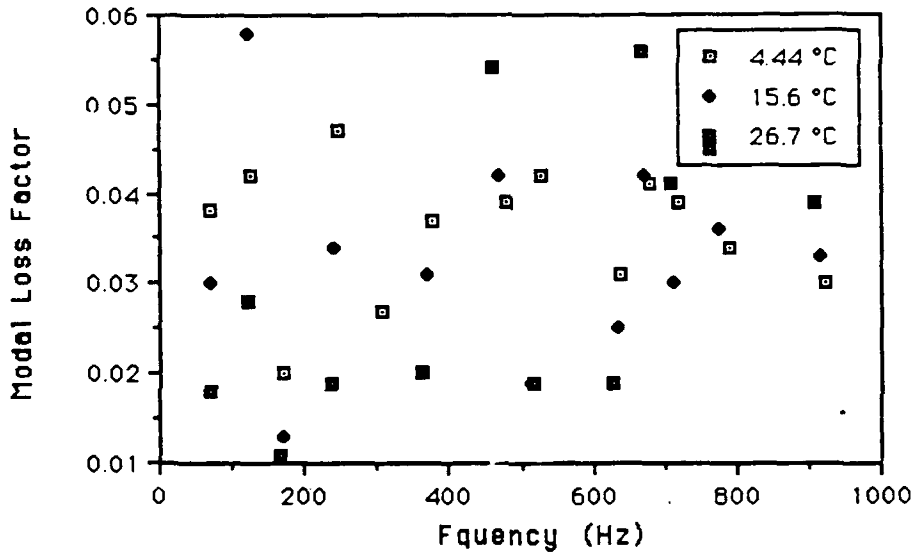

Figure 3.13. Measured Modal Loss Factors for the Line Welded Pocket Plate Configuration at 4.44/15.6/26.7 °C.

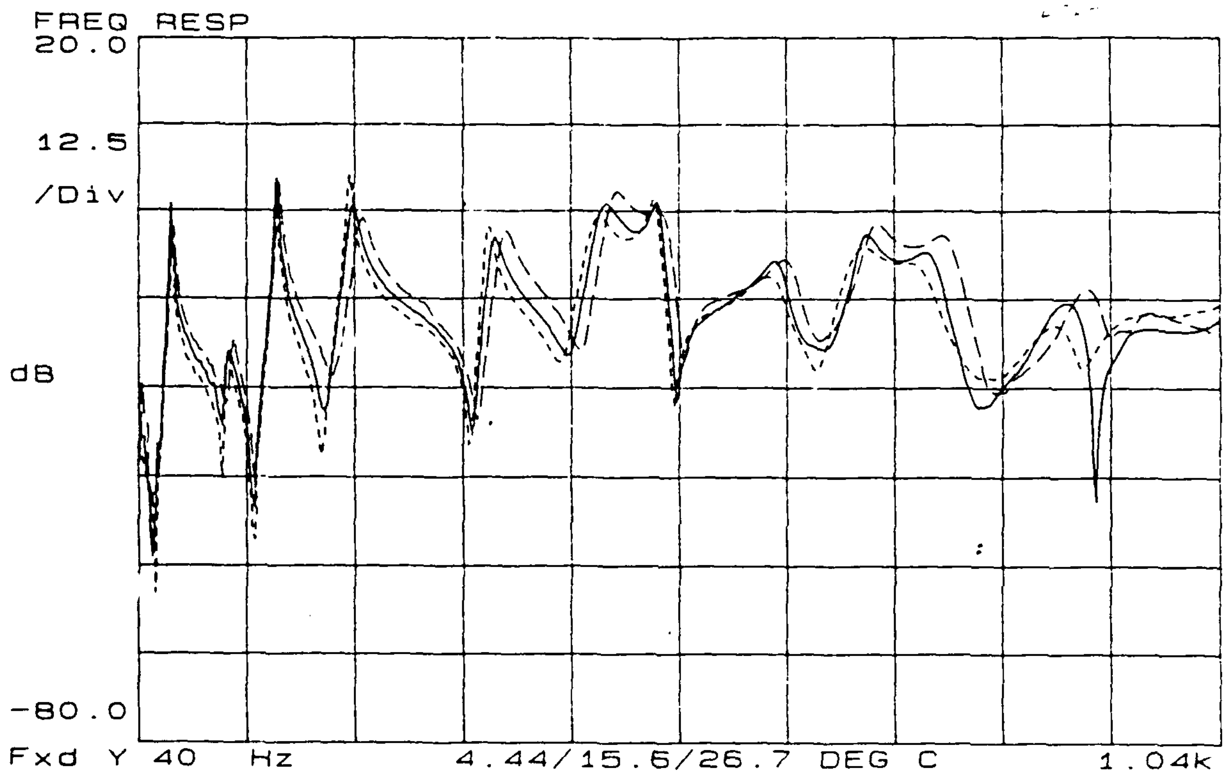

Figure 3.14. Measured Frequency Response of the Line Welded Pocket Plate Configuration at 4.44/15.6/26.7 °C.

[— — —: 4.44 °C, ———: 15.6 °C, - - - -: 26.7°C]

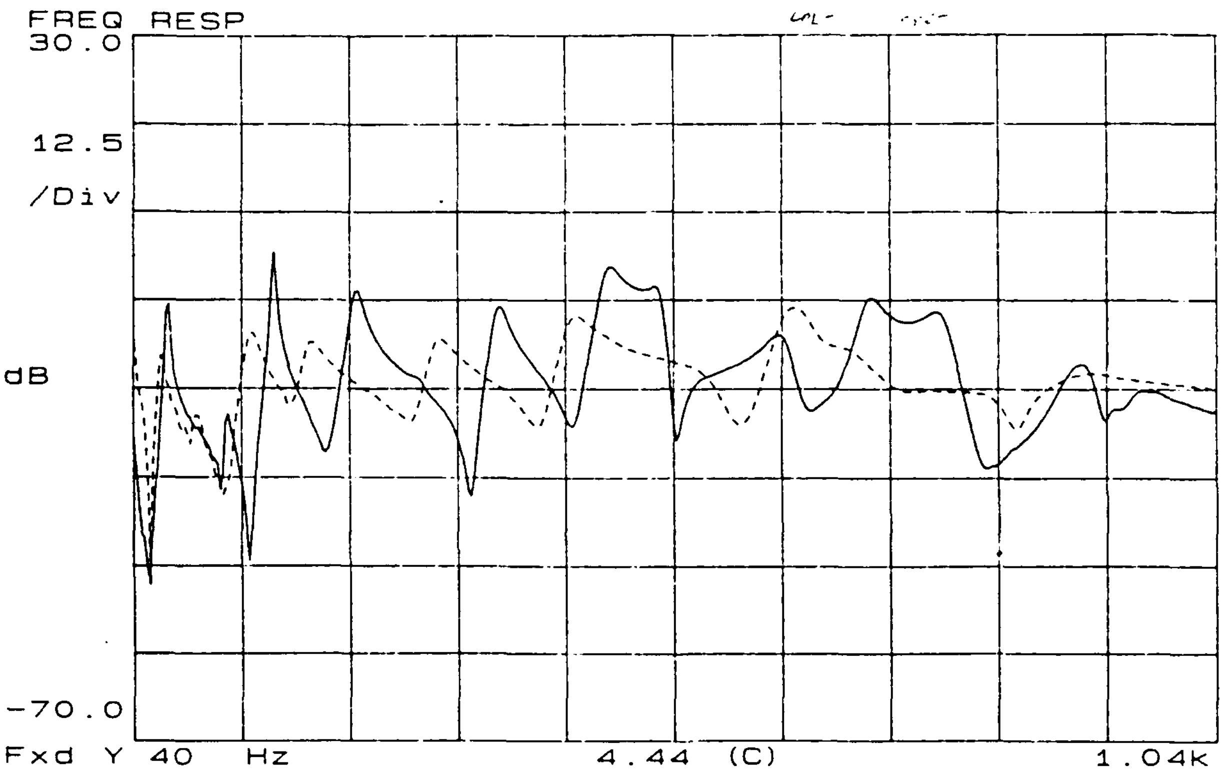

Figure 3.15. Comparison of Measured Frequency Responses of Spot and Line Welded Pocket Plates at 4.44 °C.

[- - - - : Spot Welded, ——— : Line Welded]

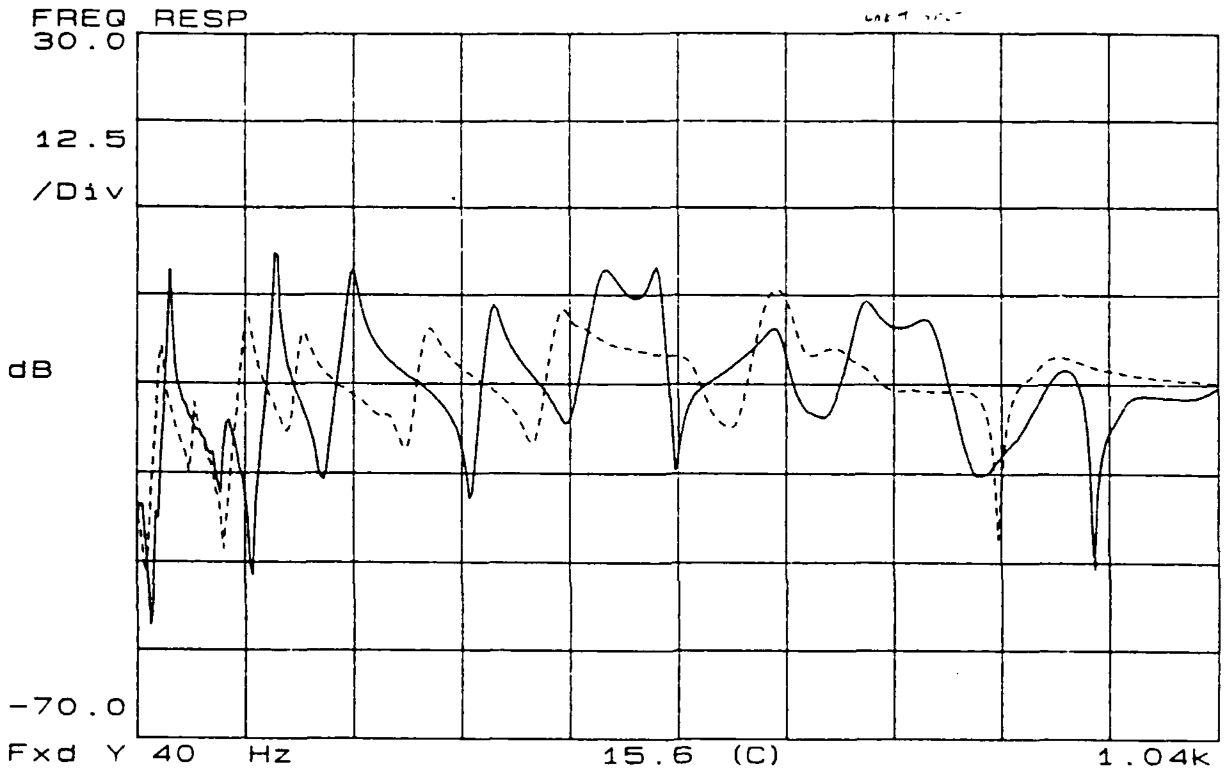

Figure 3.16. Comparison of Measured Frequency Responses of Spot and Line Welded Pocket Plates at 15.6 °C.

[- - - - : Spot Welded, ——— : Line Welded]

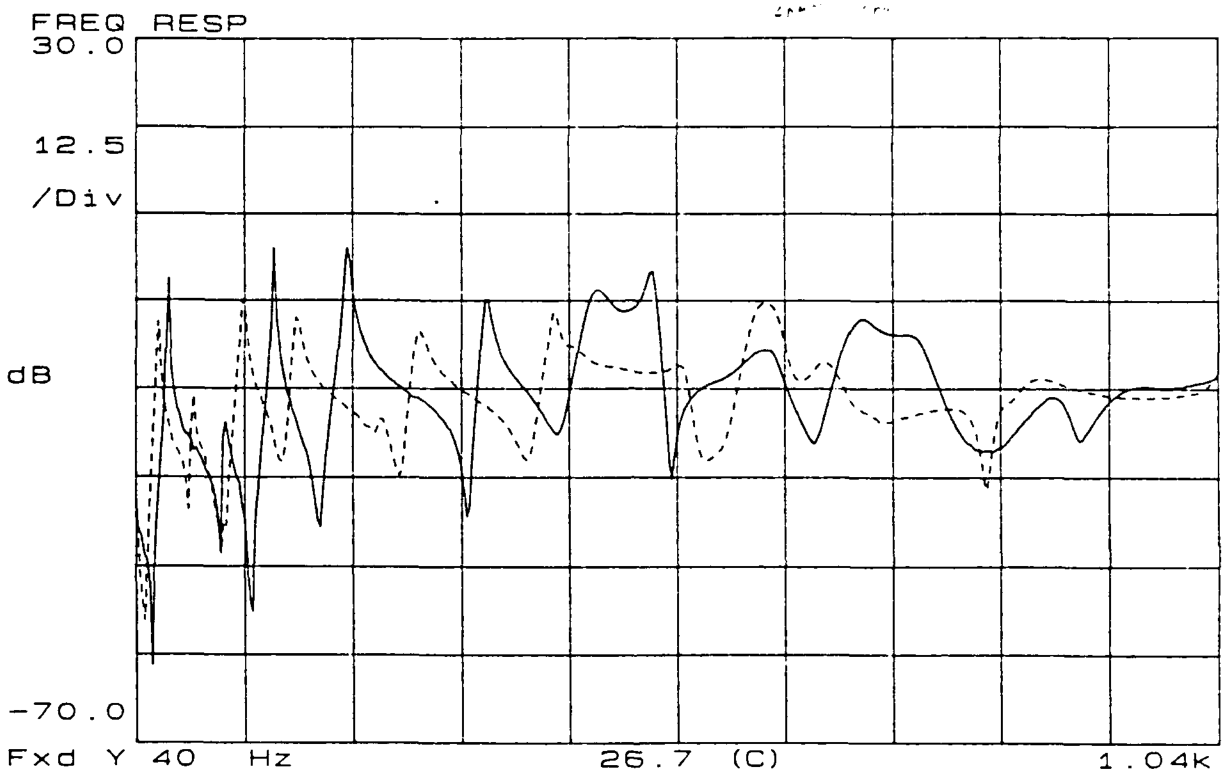

Figure 3.17. Comparison of Measured Frequency Responses of Spot and Line welded Pocket Plates at 26.7 °C.

[- - - - : Spot Welded, —— : Line Welded]

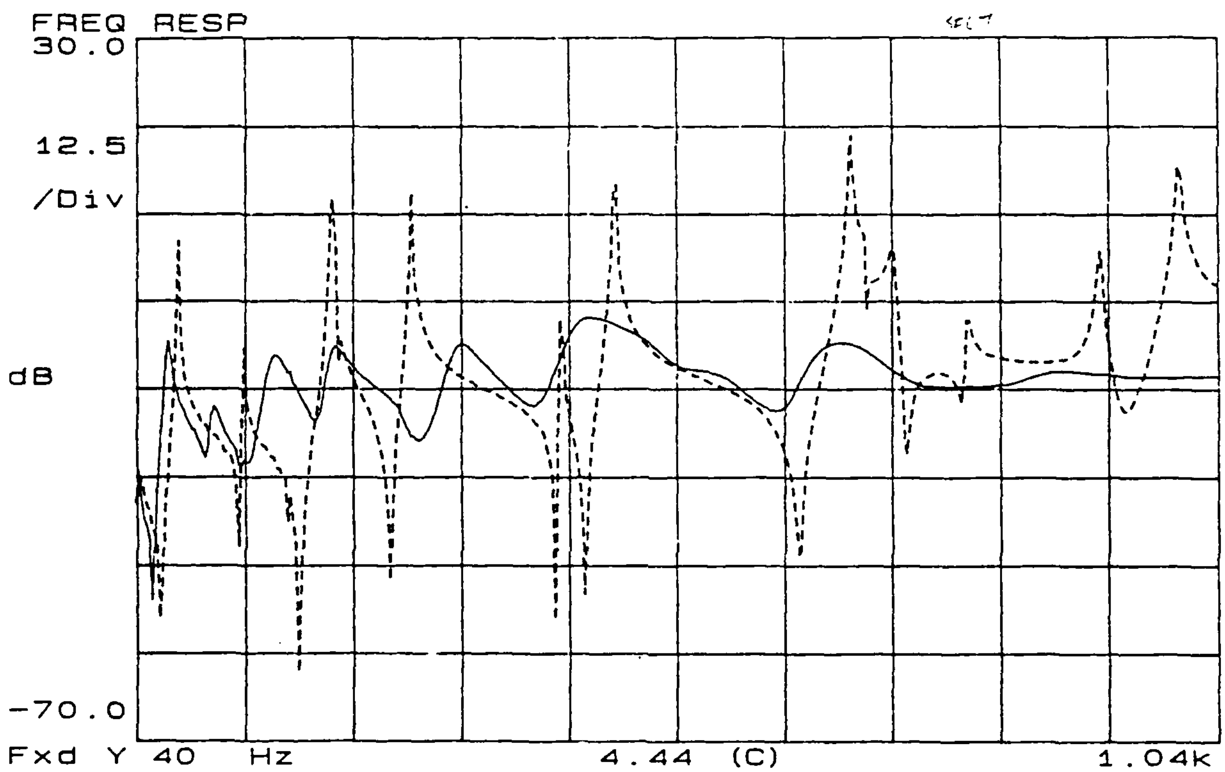

Figure 3.18. Measured Frequency Response of the Spot Welded Floating Element Plate at 4.44 °C.

[- - - - : undamped response; ——— : damped response]

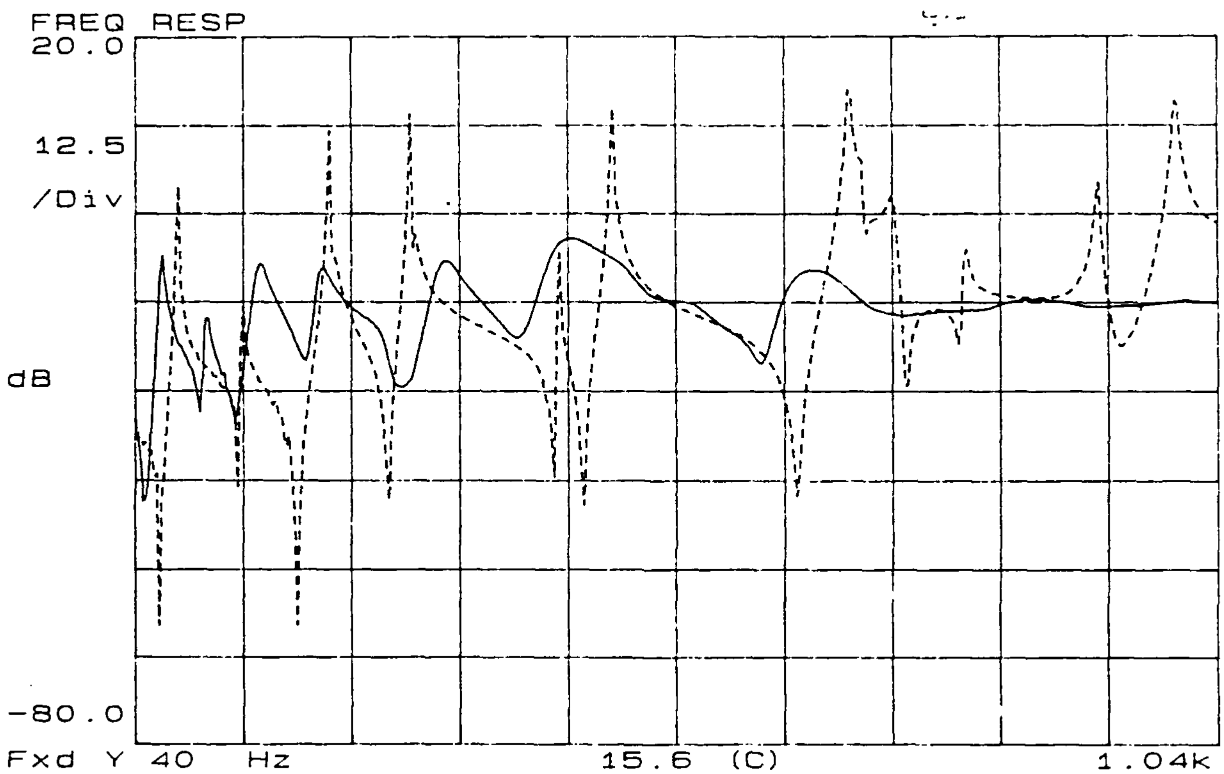

Figure 3.19. Measured Frequency Response of the Spot Welded Floating Element Plate at 15.6 °C.

[- - - - : undamped response; ——— : damped response]

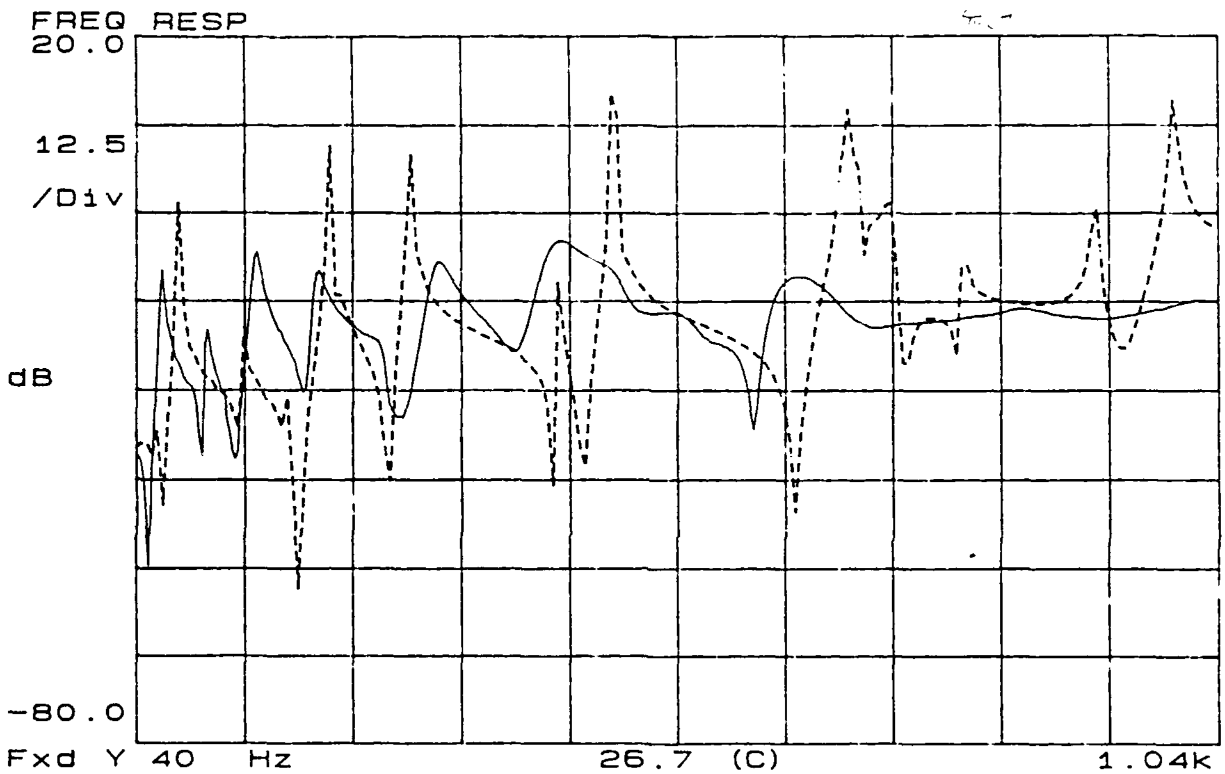

Figure 3.20. Measured Frequency Response of the Spot Welded Floating Element Plate at 26.7 °C.

[- - - - : undamped response; ——— : damped response]

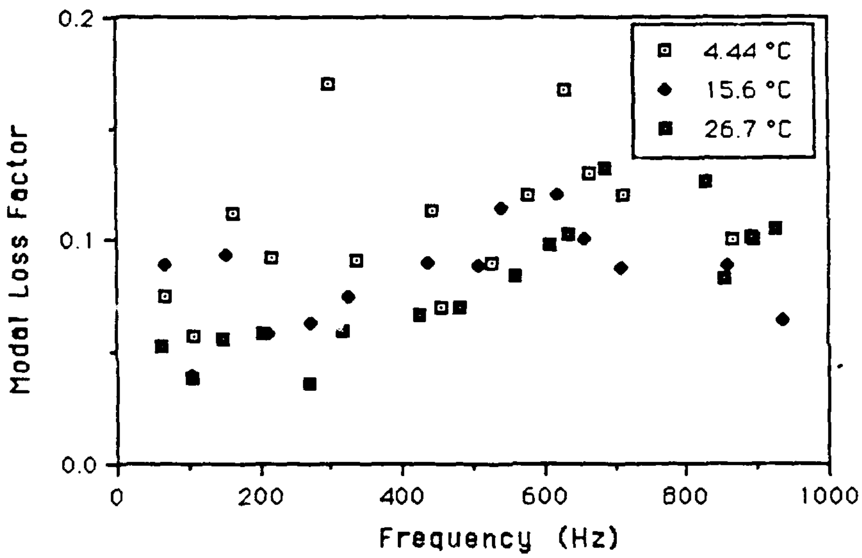

Figure 3.21. Measured Modal Loss Factors for the Spot Welded Floating Element Plate at 4.44/15.6/26.7 °C.

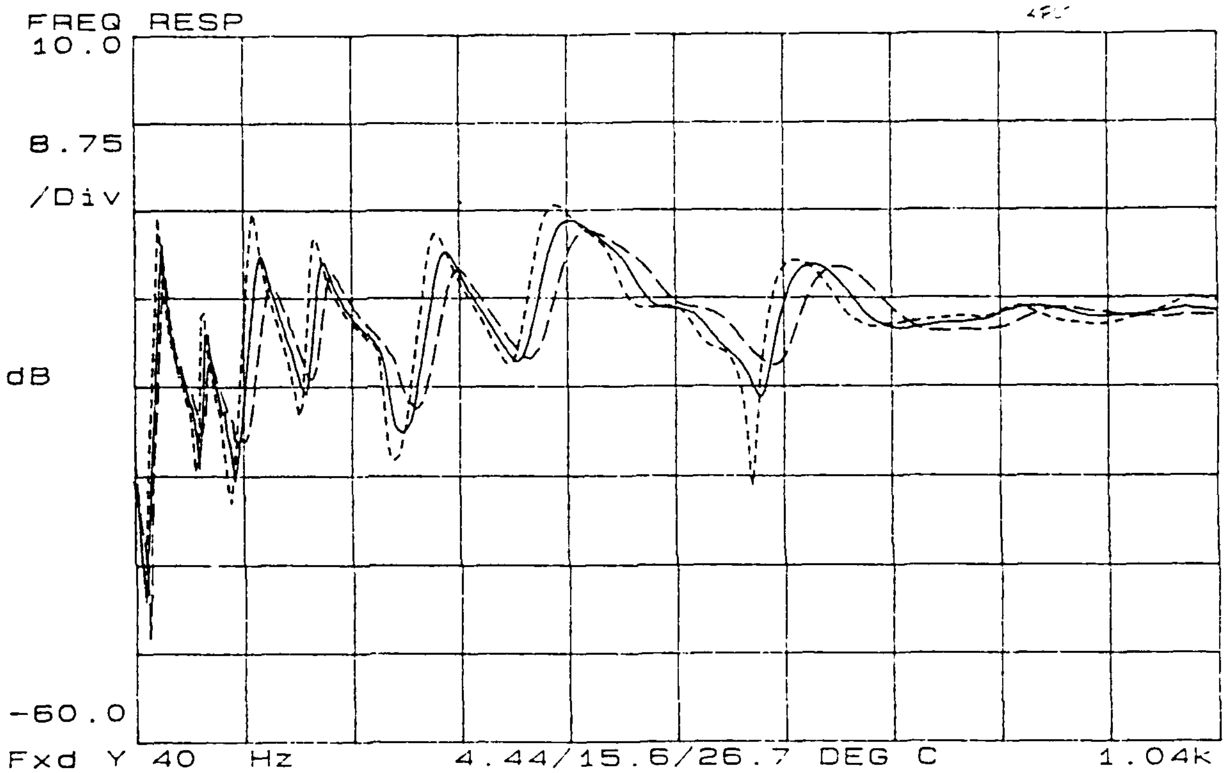

Figure 3.22. Measured Frequency Response of the Spot Welded Floating Element Plate at 4.44/15.6/26.7 °C.

[— — —: 4.44 °C, ———: 15.6 °C, - - - -: 26.7°C]

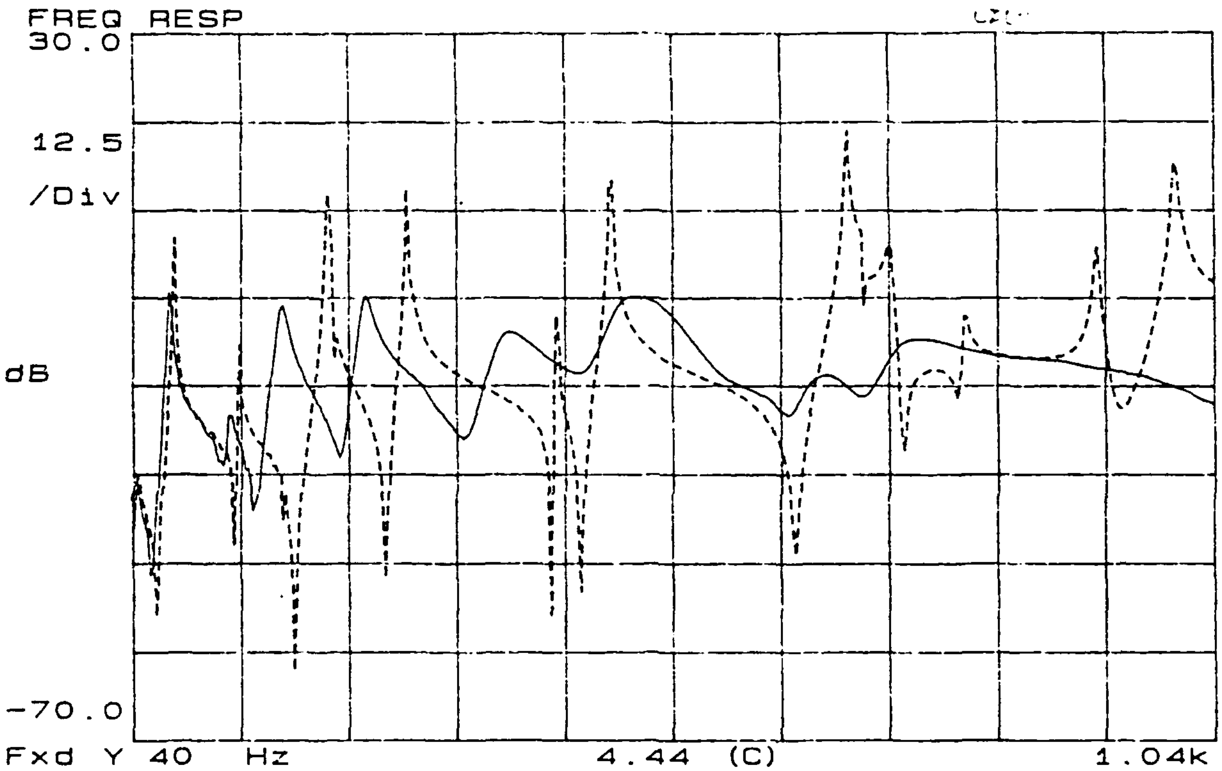

Figure 3.23 Measured Frequency Response of the Line Welded Floating Element Plate at 4.44 °C.

[- - - - : undamped response; ——— : damped response]

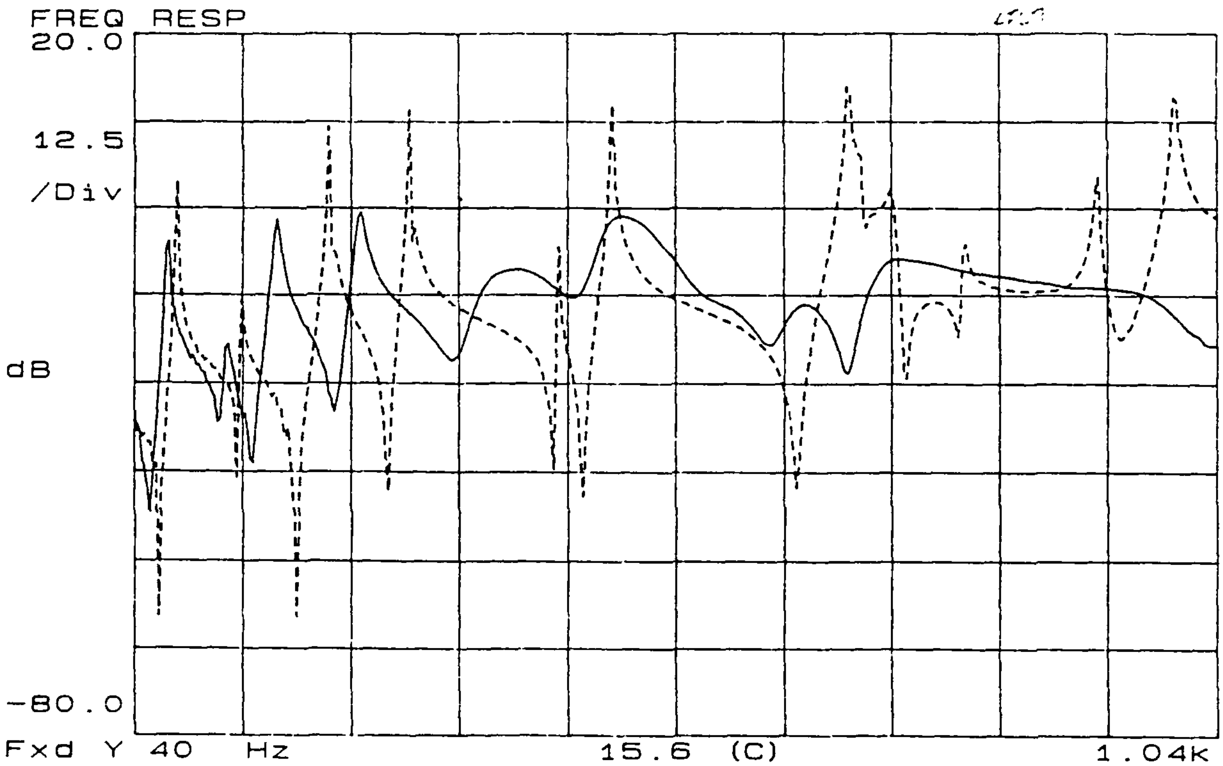

Figure 3.24. Measured Frequency Response of the Line Welded Floating Element Plate at 15.6 °C.

[- - - - : undamped response; ——— : damped response]

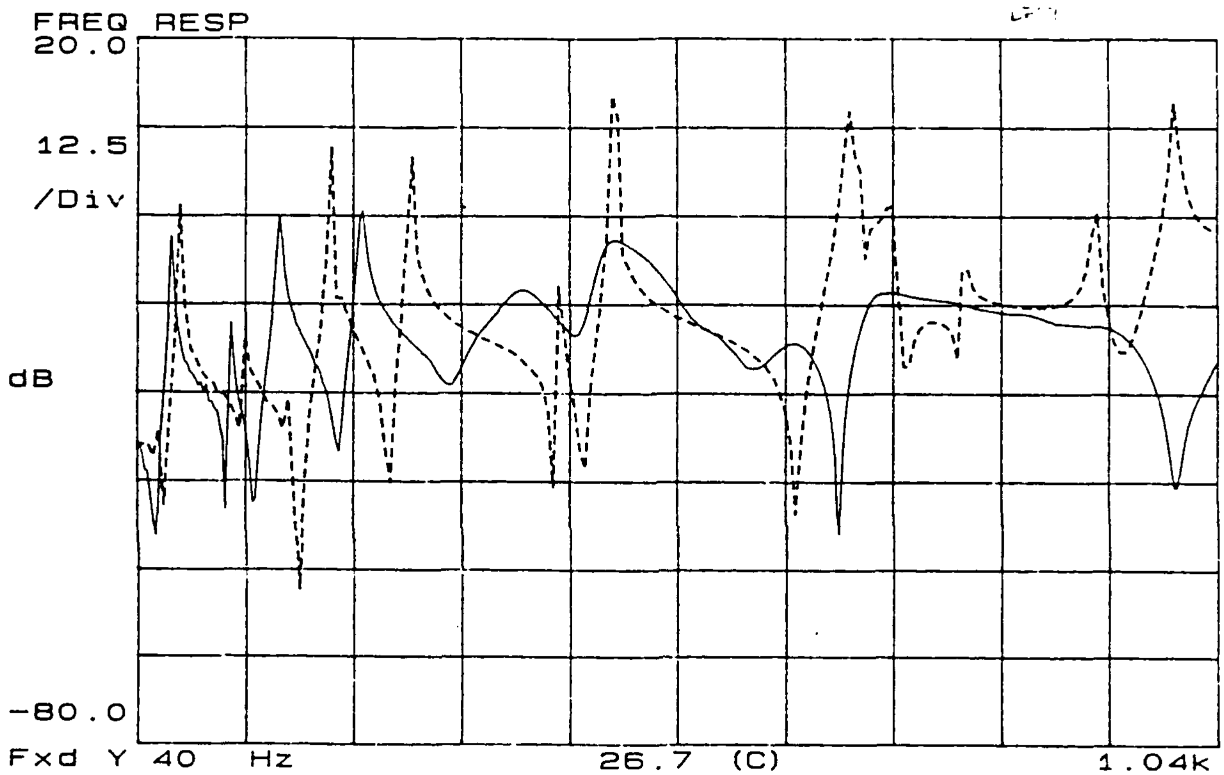

Figure 3.25. Measured Frequency Response of the Line Welded Floating Element Plate at 26.7 °C.

[- - - - : undamped response; ——— : damped response]

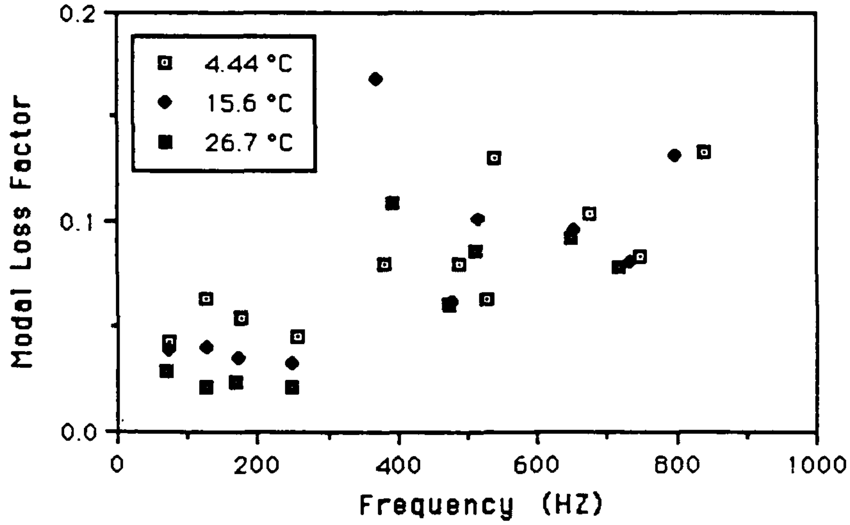

Figure 3.26. Measured Modal Loss Factors for the Line Welded Floating Element Plate at 4.44/15.6/26.7 °C.

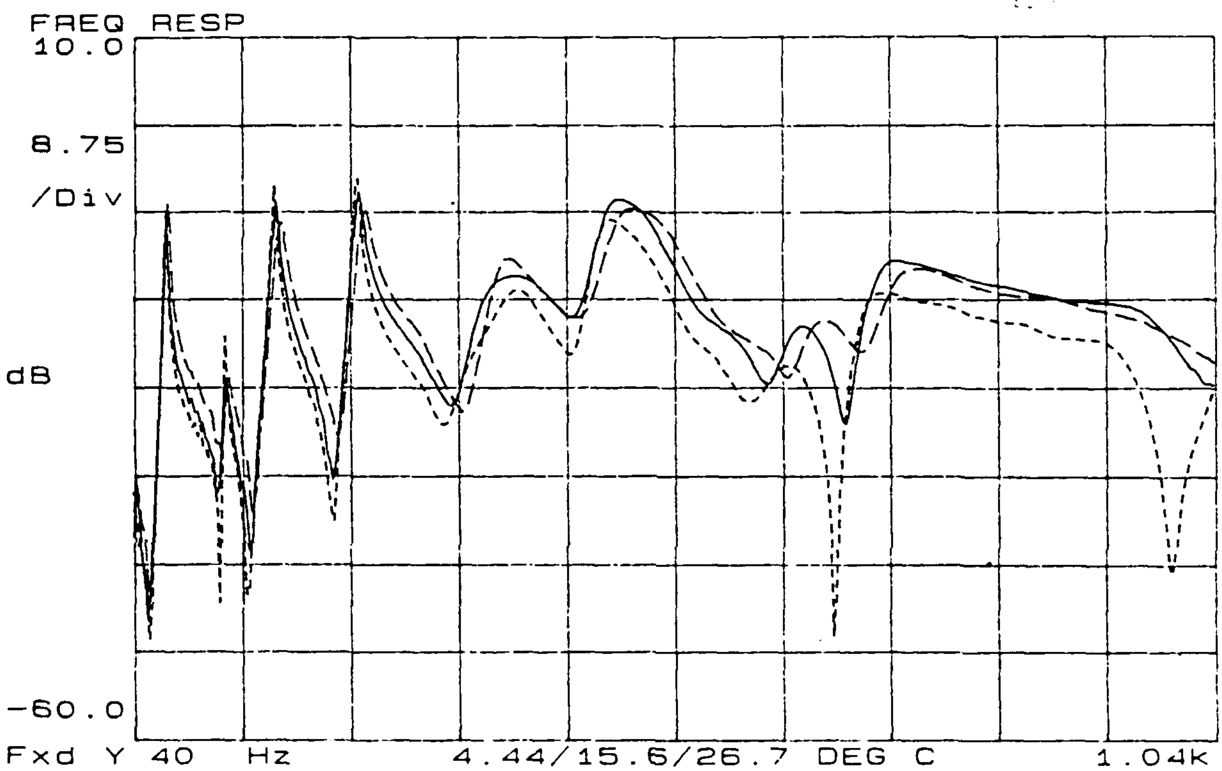

Figure 3.27. Measured Frequency Response of the Line Welded Floating Element Plate at 4.44/15.6/26.7 °C.

[— — —: 4.44 °C, ———: 15.6 °C, - - - -: 26.7°C]

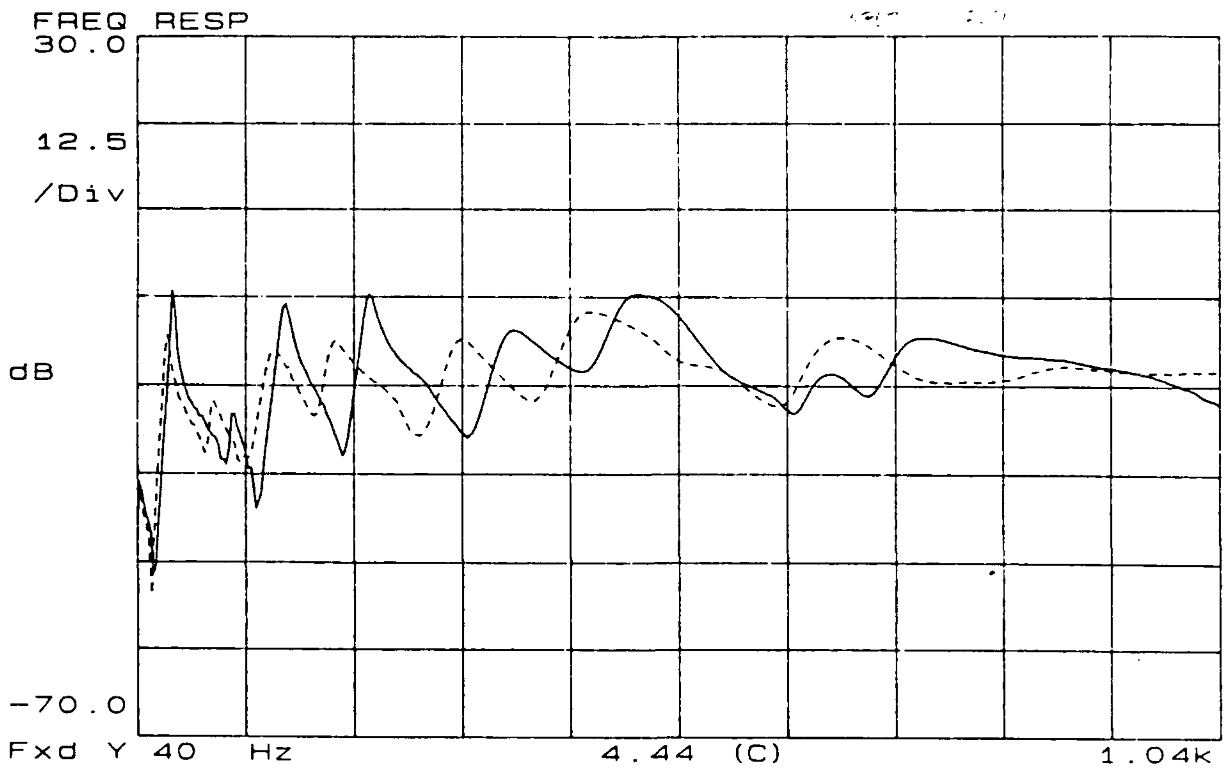

Figure 3.28. Comparison of Measured Frequency Responses of Spot and Line Weld Floating Element Plate at 4.44 °C.

[- - - - : Spot Welded, —— : Line Welded]

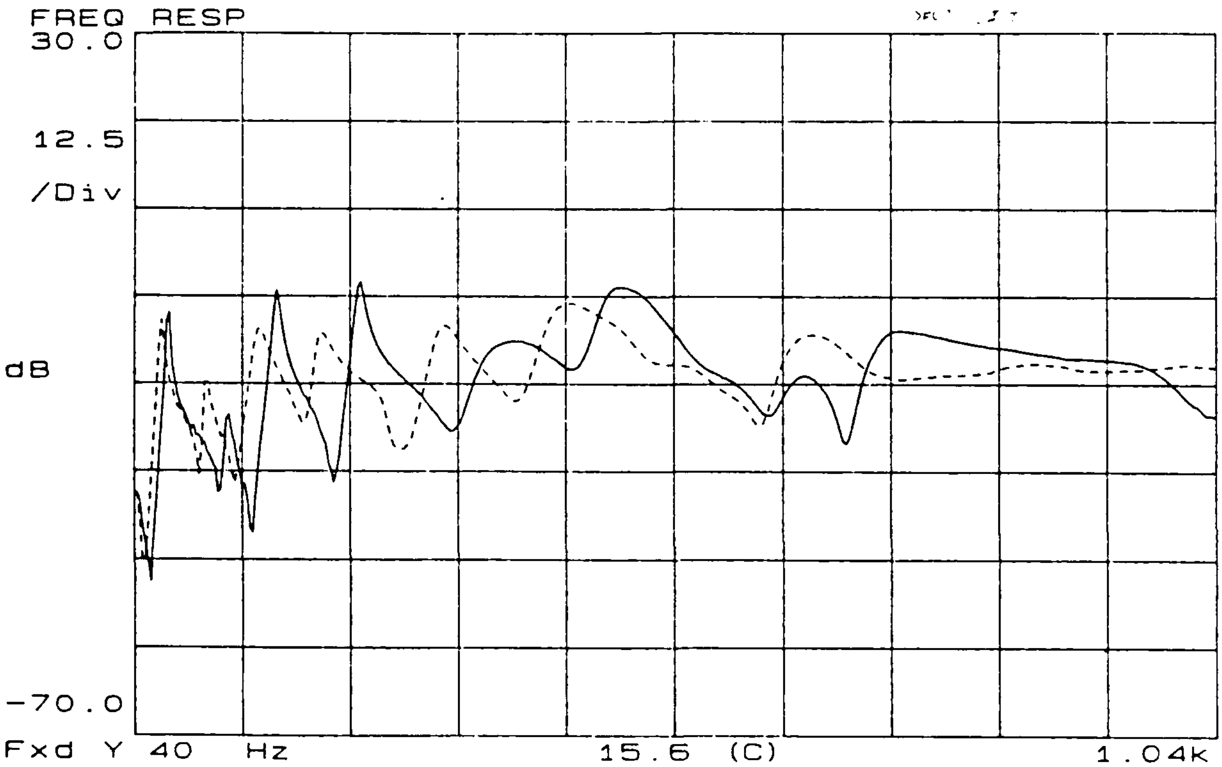

Figure 3.29. Comparison of Measured Frequency Responses of Spot and Line Welded Floating Element Plate at 15.6 °C.

[- - - - : Spot Welded, —— : Line Welded]

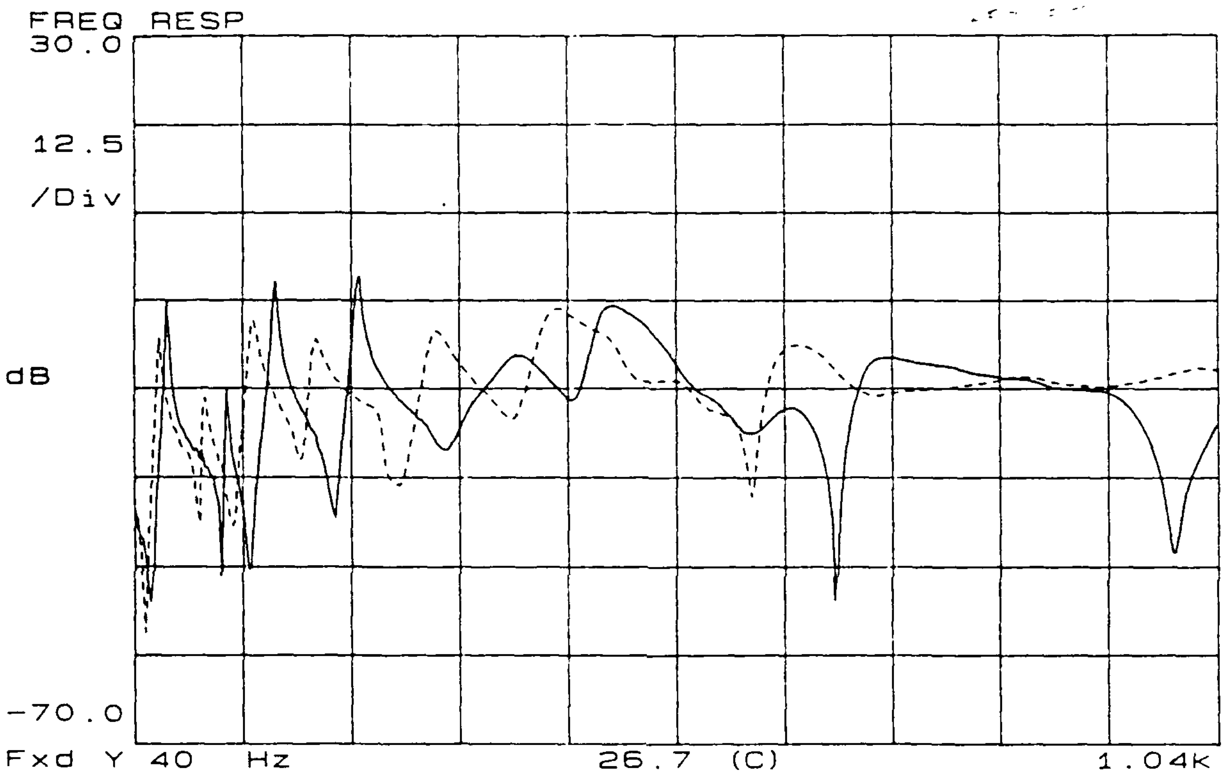

Figure 3.30. Comparison of Measured Frequency Responses of Spot and Line Welded Floating Element Plate at 26.7 °C.

[- - - - : Spot Welded, —— : Line Welded]

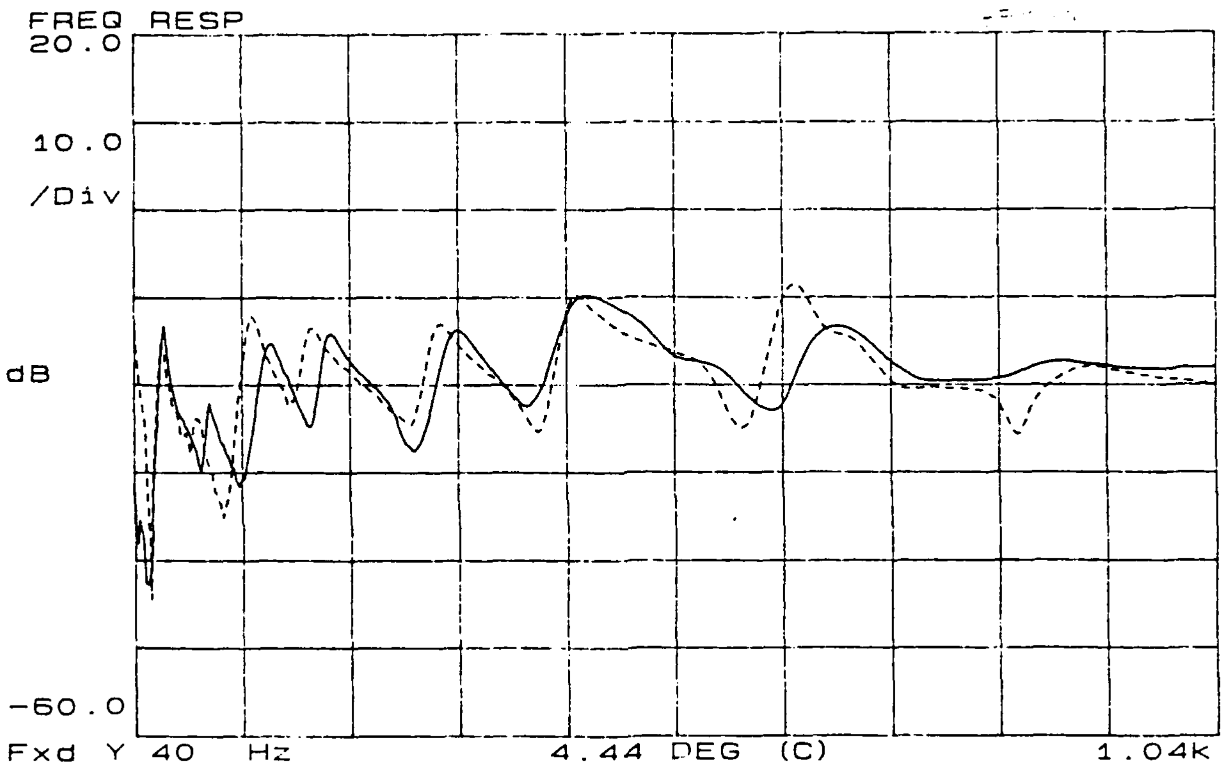

Figure 3.31. Comparison of Measured Frequency Response of Spot Welded Pocket Plate and Floating Element Plate at 4.44 °C.

[- - - - : Pocket Plate, ——— : Floating Element]

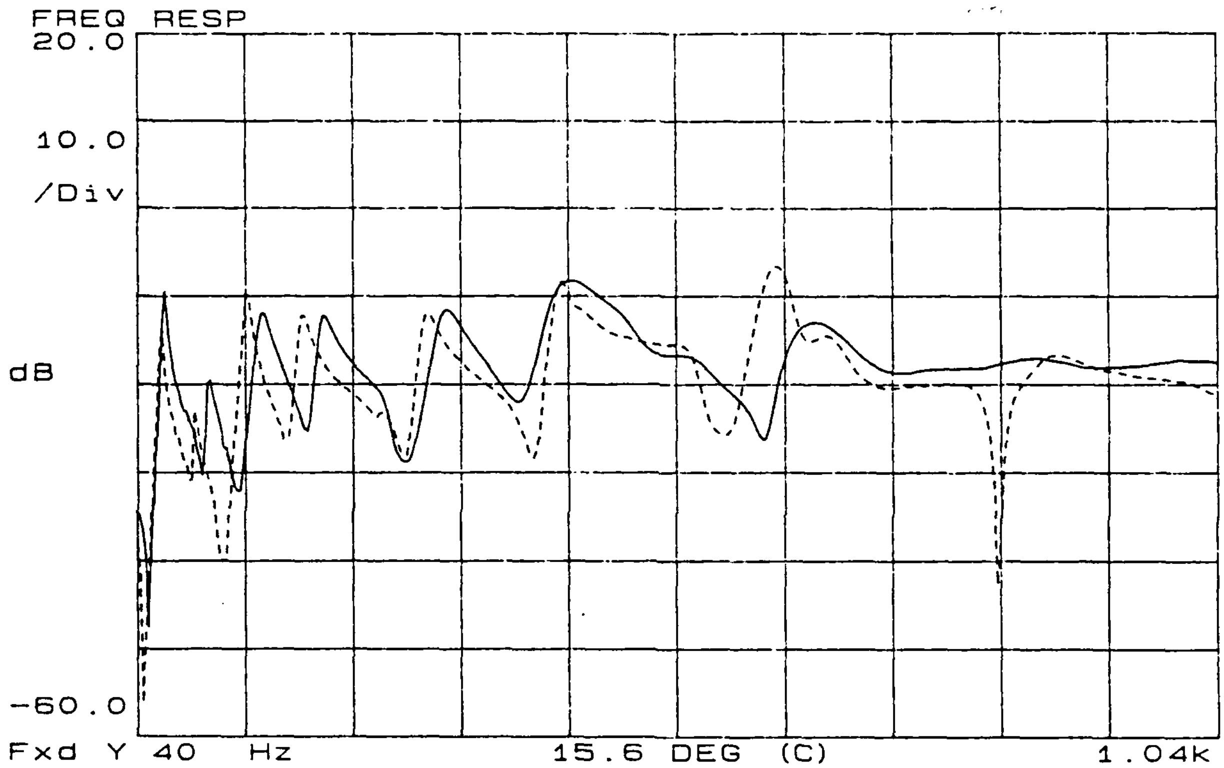

Figure 3.32. Comparison of Measured Frequency Response of Spot Welded Pocket Plate and Floating Element Plate at 15.6 °C.

[- - - - : Pocket Plate, —— : Floating Element]

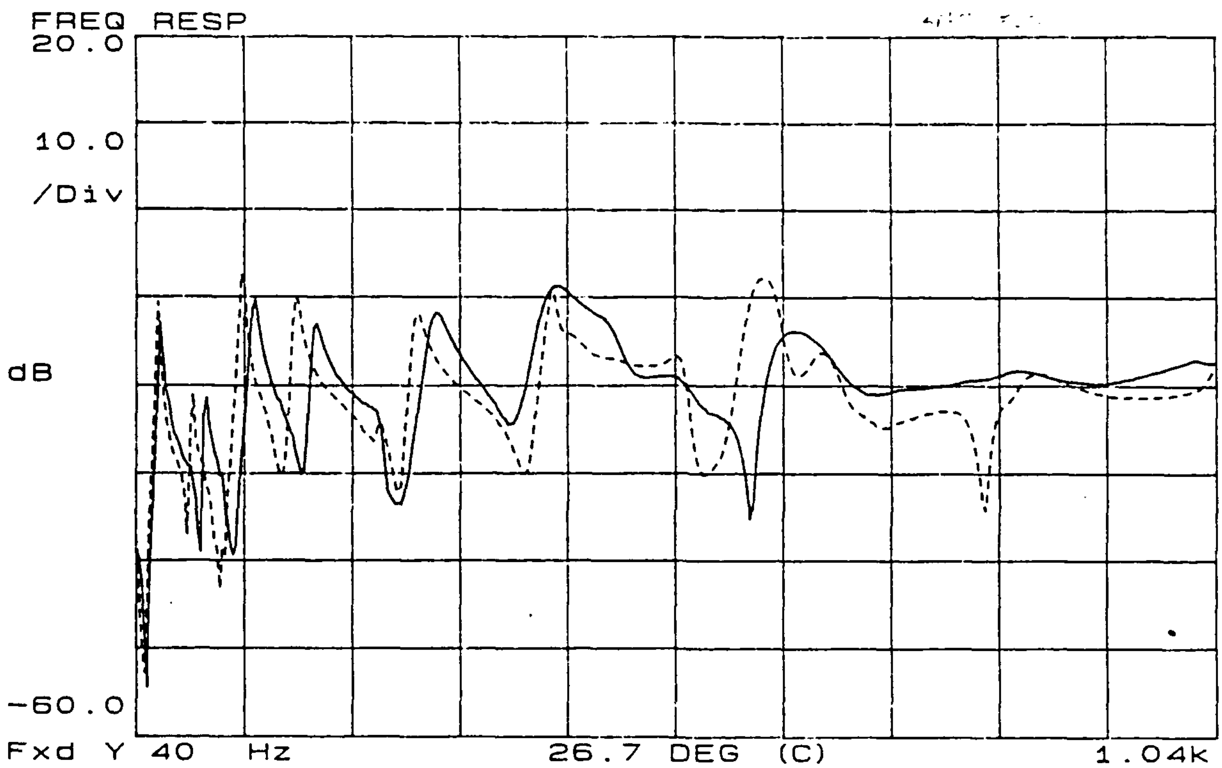

Figure 3.33. Comparison of Measured Frequency Responses of Spot Welded Pocket Plate and Floating Element Plate at 26.7 °C.

[- - - - : Pocket Plate, ——— : Floating Element]

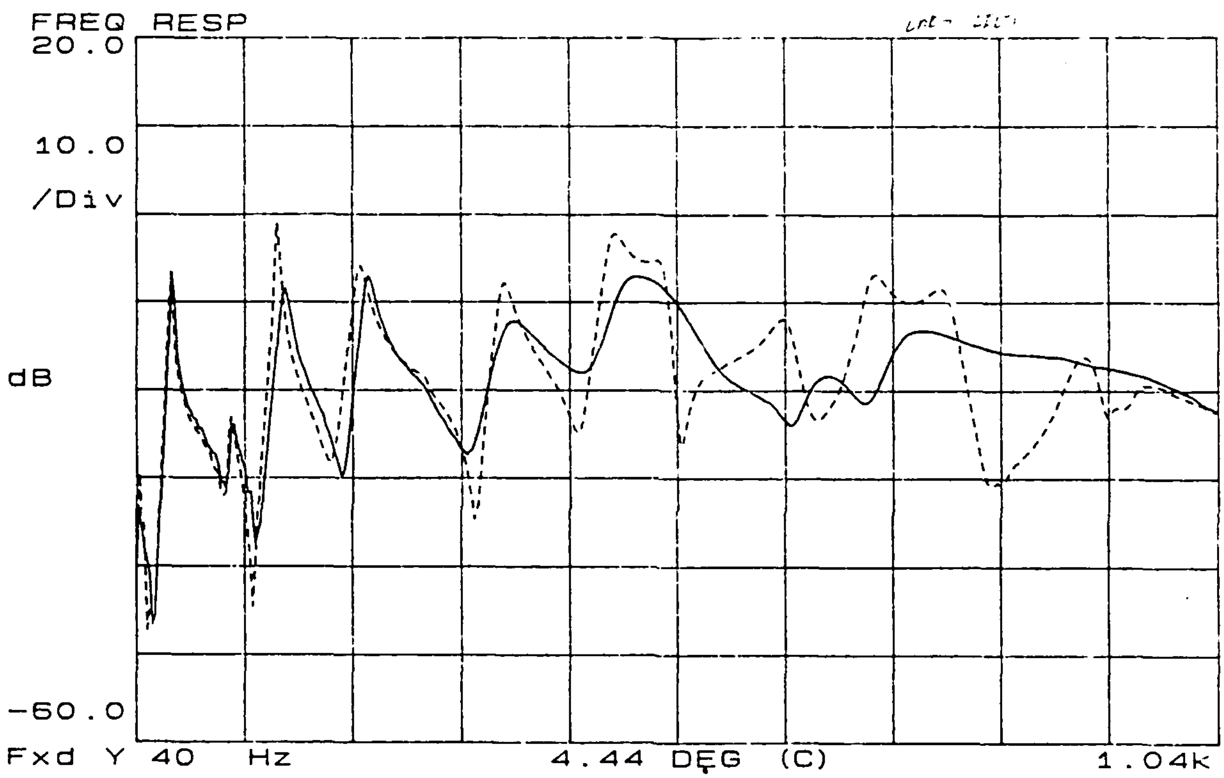

Figure 3.34. Comparison of Measured Frequency Response of Line Welded Pocket Plate and Floating Element Plate at 4.44 °C.

[- - - - : Pocket Plate, —— : Floating Element]

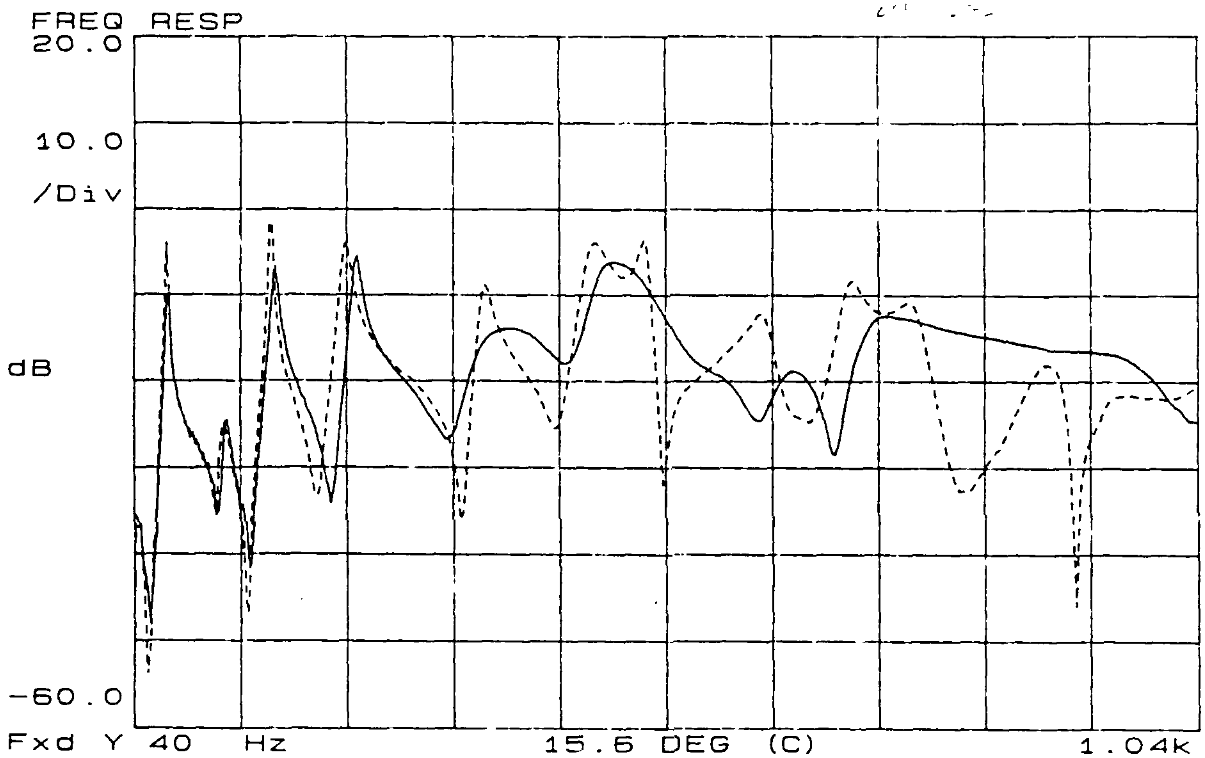

Figure 3.35. Comparison of Measured Frequency Response of Line Welded Pocket Plate and Floating Element Plate at 15.6 °C.

[- - - - : Pocket Plate, —— : Floating Element]

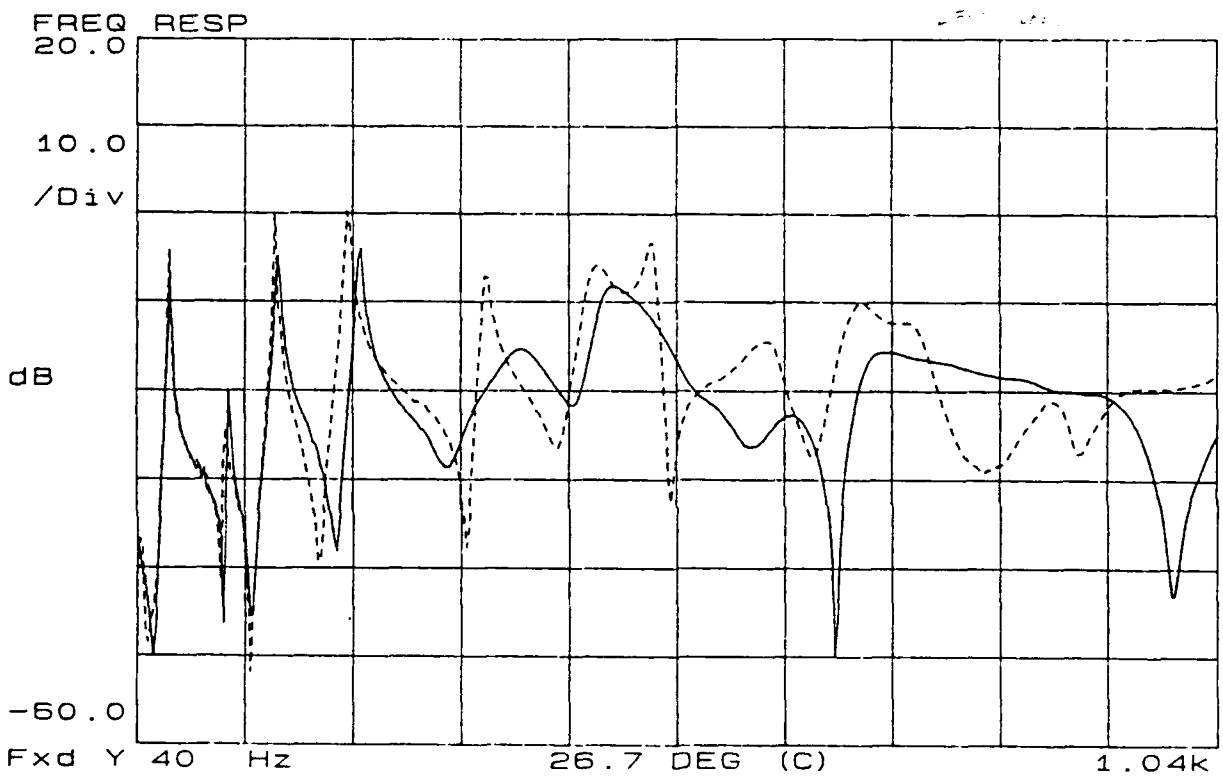

Figure 3.36. Comparison of Measured Frequency Responses of Line Welded Pocket Plate and Floating Element Plate at 26.7 °C.

[- - - - : Pocket Plate, —— : Floating Element]

IV. FINITE ELEMENT ANALYSIS

A. POCKET PLATE RESULTS

A finite element representation of the pocket plate model is shown in Figure 4.1. The cover plate and base plate were modeled using the 4-node QUAD elements. The viscoelastic material and the structure surrounding it were modeled using 8-node HEXA elements. In the spot welded plate, a welded point is shared a single finite element node between cover plate and base structure. The other non-welded points that are corresponding to the same geometric point were belong to two different finite element nodes; one to cover plate and the other to base structure. In the continuous line welded plate all the welded point were shared the same finite element nodes.

Modal strain energy method was introduced to calculate the modal frequencies and modal loss factors. Five separate runs were conducted using the viscoelastic material properties of ISD-112 at 50, 200, 500, 800, and 1000 Hz, and at three temperatures to extract the normal modes. Using these reference frequencies we get a composite set of modal loss factors. In addition to the modal frequencies, the strain energy in the viscoelastic elements and the entire model were output from MSC/NASTRAN.

Since the shear modules of a viscoelastic material changes with frequency, it was necessary to estimate the actual modal frequencies of the damped plate using an interpolation procedure outlined by Johnson and

Kienholz [Ref. 7]. The first step of the interpolation process was to plot the shear modulus of ISD-112 versus frequency from 5 to 1000 Hz. Then, for the first mode, using NASTRAN results based on ISD-112 material properties at 50 Hz, the first modal frequency predicted by MSC/NASTRAN and the corresponding shear modulus were plotted. The same was then done using the first natural frequency predicted by normal mode extraction based on ISD-112 material properties at frequencies of 200, 500, 800, and 1000 Hz. A curve was then passed through these five points. The point where the MSC/NASTRAN modal frequencies for the first mode intersected the ISD-112 shear modulus curve was taken to be the interpolated modal frequency of the spot welded pocket plate configuration. A plot of the intersection of these two curves for the first 17 modes is shown in Figure 4.2.

Once the interpolated modal frequencies were found, the modal strain energy equations (2-5) and (2-6) were used to compute modal loss factors for the single layer configuration. A set of modal loss factors was computed based on the modal strain energies computed using viscoelastic properties at reference frequencies of 50, 200, 500, 800, and 1000 Hz. A set of composite modal loss factors for the modal frequencies near these reference frequencies was then selected The resulting modal loss factors are shown in Table 4.1 and are plotted versus frequency in Figure 4.3 As seen in Figure 4.3, the modal strain energy method is predicting high damping for this configuration with an average modal loss factor of 0.132.

Using the set of composite modal loss factors, the frequency response of the damped plate was computed using MSC/NASTRAN. Modal damping was introduced to the model using the SDAMP option in the Case Control Deck and the TABDMP1 damping table in the Bulk Data Deck as described in the MSC/NASTRAN Handbook for Dynamic Analysis [Ref. 8]. Since MSC/NASTRAN uses a linear interpolation between points in the damping table to describe the modal damping in the model [Ref. 8], a simple curve fit was applied to the set of composite modal loss factors as shown in Figure 4.3. Points from this curve fit were then used in the MSC/NASTRAN damping table. To compute the frequency response, a unit excitation force was applied at the same node as the undamped plate, and the node used for the response was also the same as the undamped plate [Ref. 2].

1. Spot Welded Pocket Plate Results

These loss factors for spot welded pocket plate based on 4.44 °C (40 °F), 15.6 °C(60 °F), and 26.7 °C (80 °F) are listed in Table 4.1. The estimated loss factor versus frequency are shown in Figure 4.4. The damping values used for the frequency response calculation in MSC/NASTRAN came from a curve-fit to the set of composite modal loss factors.

The results of the frequency response calculations are shown in Figures 4.5, through 4.7. The dashed line represents the undamped reference plate, and the solid line represents the modal frequency response of the spot welded pocket plate configuration. Material properties at 200 Hz were used for the ISD-112 damping material. The first thirty modes were used in the modal summation for the response. A listing of the MSC/NASTRAN data deck used to compute the modal frequency response is in Appendix D.

The modal loss factors estimated using the modal strain energy method are compared to those measured experimentally for the spot welded pocket plate in Figure 4.8. The estimated loss factors are greater than the experimentally determined loss factors throughout the spectrum of interest, and especially in the middle frequencies.

The frequency response of the spot welded pocket plate is compared to the experimentally measured frequency response are shown in Figures 4.9, through 4.11. The comparison was accomplished by normalizing both the experimentally determined frequency response and the frequency response computed by MSC/NASTRAN. Both responses were normalized using a value of 1.0 $\frac{in/sec^2}{lb}$. The effects of the greater loss factors estimated by the modal strain energy method are obvious as the level of the predicted response is lower than the measured response. The shift in frequency between the two curves is due to the finite element model being inherently stiffer than the actual system. The correlation between the two curves is especially good below 250 Hz as this is where the differences between estimated and measured modal loss factors are the least.

TABLE 4.1. ESTIMATED MODAL LOSS FACTORS FOR THE SPOT WELDED POCKET PLATE AT 4.44/15.6/26.7 °C.

4.44 °C (60 °F)		15.6 °C (60 °F)		26.7 °C (80 °F)	
f (Hz)	n	f (Hz)	n	f (Hz)	n
68.2	0.063	67.0	0.046	66.0	0.025
110.7	0.056	109.0	0.034	107.8	0.018
169.4	0.117	162.0	0.091	158.0	0.053
224.3	0.090	217.5	0.063	213.8	0.036
307.7	0.140	295.0	0.091	287.0	0.047
346.6	0.103	333.0	0.047	324.5	0.055
472.1	0.116	453.0	0.070	441.9	0.049
498.5	0.112	477.0	0.093	460.1	0.073
507.2	0.160	511.0	0.113	463.5	0.064
541.7	0.163	588.0	0.104	490.9	0.078
611.1	0.133	625.0	0.086	571.0	0.055
647.1	0.122	668.0	0.089	609.1	0.048
685.9	0.087	713.0	0.077	651.0	0.055
732.4	0.112	831.0	0.077	698.7	0.042
856.7	0.096	834.0	0.065	814.4	0.042
860.9	0.098	868.0	0.051	820.6	0.034
898.7	0.040			852.7	0.031

2. Line Welded Pocket Plate Results

The estimated loss factors for the line welded pocket plate based on 4.44 °C (40 °F), 15.6 °C (60 °F), and 26.7°C (80 °F) are listed in Table 4.2 and are plotted versus frequency shown in Figure 4.12. The estimated loss factors for line welded pocket plate also give good damping. The modal frequency response of the line welded pocket plate were computed using the first 30 modes and viscoelastic material properties at 200 Hz. The results of the frequency response calculations are shown in Figures 4.13, through 4.15. The dashed line represents the undamped reference plate, and the solid line represents the frequency response of the line welded pocket plate. The modal loss factors estimated using the modal strain energy method are compared to those measured experimentally for the line welded pocket plate configuration in Figure 4.16. The estimated loss factors are greater than the experimentally measured loss factors throughout the spectrum of interest, and especially in the middle freqencies.

The frequency response of the line welded pocket plate is compared to the experimentally measured frequency response in Figures 4.17, through 4.19. The correlation between the two curves is especially good below 250 Hz as this is where the differences between estimated and measured modal loss factors are the least. The comparison of estimated spot and line welded pocket plate at 4.44 °C (40 °F), 15.6 °C (60 °F), and 26.7°C (80 °F) are shown in Figures 4.20, through 4.22. As can be seen from the figure, the spot welded pocket plate is more damped than line welded pocket plate. The reason is the line welded pocket plate was more constrained than spot welded one that make it hard to deform to get more shear than less damped ,less loss factor increase. From Figure 4.4 and Figure 4.12, we can see both the three lines have similar trend that loss factor increase to the peak at frequency about 500 Hz. Lower the temperature the viscoelastic material gets stiffer that increase the damped effect. So, the lowest reference temperature (4.44 °C) plate has highest modal loss factor .On the other hand the highest reference temperature (26.7 °C) plate has the lowest modal loss factor. The same trend was shown in the experimental measurements.

TABLE 4.2. ESTIMATED MODAL LOSS FACTORS FOR THE LINE WELDED POCKET PLATE AT 4.44/15.6/26.7 °C.

4.44 °C (60 °F)		15.6 °C (60 °F)		26.7 °C (80 °F)	
f (Hz)	η	f (Hz)	η	f (Hz)	η
70.6	0.020	70.2	0.012	70.0	0.006
122.8	0.008	122.6	0.005	122.4	0.003
179.4	0.058	176.1	0.040	174.0	0.022
249.7	0.030	247.2	0.024	245.5	0.014
323.3	0.089	314.6	0.058	309.4	0.030
388.1	0.044	381.0	0.042	376.0	0.028
491.3	0.084	477.2	0.060	469.2	0.033
545.2	0.060	533.9	0.054	525.2	0.034
546.7	0.064	534.6	0.038	528.8	0.020
585.8	0.072	571.2	0.054	562.0	0.033
661.5	0.067	644.6	0.054	633.3	0.037
690.9	0.084	669.8	0.061	658.2	0.033
731.6	0.061	714.4	0.050	703.5	0.031
800.4	0.079	776.7	0.059	762.7	0.036
881.3	0.054	864.6	0.034	855.7	0.019
944.7	0.052	925.7	0.038	914.7	0.023
		944.3	0.044	932.0	0.024

B. FLOATING ELEMENT PLATE RESULTS

The base plate and cover plate were modeled using the 4-node QUAD elements. The two viscoelastic material, an aluminum plate between two viscoelastic material, and the structure surrounding it were modeled using 8-node HEXA elements. In the spot welded floating element plate, a welded point is shared a single finite element node between cover plate and base structure, the other non-welded points that are corresponding to the same geometric point were belong to two different finite element nodes; one to cover plate and the other to base structure. In the continuous line welded floating element all the welded point were shared the same finite element nodes. A finite element representation of the floating element plate model is shown in Figure 4.23.

Modal strain energy method was used to calculate the modal frequencies and modal loss factors. We use viscoelastic material at 50, 200, 500, 800, and 1000 Hz to extract the normal mode. Using these reference frequencies we get a composite set of modal loss factors.

1. Spot Welded Floating Element Results

The estimated loss factors for spot welded floating element plate based on 4.44 °C (40 °F), 15.6 °C (60 °F), and 26.7 °C (80 °F) are listed in Table 4.3. The loss factor versus frequency are shown in Figure 4.24. The results of the modal frequency response calculations are shown in Figures 4.25, through 4.27. The dashed line represents the undamped reference plate, and the solid line represents the frequency response of the spot welded floating element plate. The modal loss factors estimated using the modal strain energy method are compared to those measured experimentally for the spot welded pocket plate configuration in Figure 4.28. The estimated loss factors are greater than the experimentally determined loss factors throughout the spectrum of interest, and especially in the middle frequencies.

The frequency response of the spot welded floating element configuration is compared to the experimentally measured frequency response in Figures 4.29, through 4.31. The correlation between the two curves is especially good below 250 Hz as this is where the differences between estimated and measured modal loss factors are the least.

TABLE 4.3. ESTIMATED MODAL LOSS FACTORS FOR THE SPOT WELDED FLOATING ELEMENT AT 4.44/15.6/26.7 °C.

4.44 °C (60 °F)		15.6 °C (60 °F)		26.7 °C (80 °F)	
f (Hz)	η	f (Hz)	η	f (Hz)	η
67.9	0.080	66.1	0.065	64.7	0.045
106.7	0.093	103.6	0.062	101.7	0.036
167.9	0.139	158.9	0.108	153.7	0.066
217.8	0.114	209.5	0.086	204.1	0.051
300.0	0.177	283.6	0.115	272.2	0.054
341.9	0.141	326.9	0.104	314.5	0.054
468.4	0.148	444.8	0.105	430.9	0.066
483.3	0.130	455.9	0.145	437.5	0.077
489.9	0.193	461.5	0.096	448.5	0.058
525.0	0.187	490.4	0.140	470.2	0.082
592.1	0.161	559.8	0.112	541.6	0.063
659.2	0.139	629.0	0.088	613.6	0.045
678.2	0.107	651.0	0.083	634.1	0.053
707.7	0.140	672.9	0.096	654.4	0.054
859.2	0.111	826.3	0.069	809.5	0.039
870.0	0.100	839.0	0.066	822.1	0.040
872.8	0.102	842.8	0.060	827.7	0.035

2. Line Welded Floating Element Plate Results

The estimated loss factors for line welded pocket plate based on 4.44 °C (40 °F), 15.6 °C (60 °F), and 26.7 °C (80 °F) are listed in Table 4.4 and are plotted versus frequency in Figure 4.30. The results of the modal frequency response calculations are shown in Figures 4.31, Figure 4.31, through 4.33. The dashed line represents the undamped reference plate, and the solid line represents the frequency response of line spot welded floating element configuration. The modal frequency response of the line welded floating element configuration is compared to the experimentally measured frequency response in Figures 4.34, through 4.36. The correlation between the two curves is especially good below 250 Hz as this is where the differences between estimated and measured modal loss factors are the least.

The comparison of estimated spot and line welded pocket plate at 4.44 °C (40 °F), 15.6 °C (60 °F), and 26.7 °C (80 °F) are shown in Figures 4.36, through 4.38. As can be seen from the figure, the spot welded floating element plate is more damped than line welded floating element. The reason is the line welded floating element was more constrained than spot welded one that make it hard to deform to get more shear than less damped ,less loss factor increase. From Fig 4.24, Fig 4.32, we can see both the three lines have similar trend that loss factor increase to the peak at frequency about 500 Hz. Lower the temperature the viscoelastic material gets stiffer that increase the damped effect. So, the lowest reference temperature (4.44°C) plate has highest modal loss factor .On the other hand the highest reference temperature (26.7°C) plate has the lowest modal loss factor.

TABLE 4.4. ESTIMATED MODAL LOSS FACTORS FOR THE LINE WELDED FLOATING ELEMENT AT 4.44/15.6/26.7 °C.

4.44 °C (60 °F)		15.6 °C (60 °F)		26.7 °C (80 °F)	
f (Hz)	η	f (Hz)	η	f (Hz)	η
70.6	0.036	69.8	0.035	68.9	0.032
121.3	0.048	119.7	0.040	118.3	0.027
178.6	0.080	173.6	0.063	170.1	0.041
247.1	0.061	242.0	0.052	238.2	0.035
322.1	0.119	310.4	0.079	303.3	0.043
383.8	0.070	373.0	0.065	365.4	0.044
491.3	0.113	472.4	0.079	461.8	0.044
534.4	0.089	518.0	0.066	507.7	0.041
541.5	0.091	523.7	0.073	512.2	0.045
570.5	0.103	549.7	0.081	536.2	0.052
643.5	0.110	619.0	0.084	603.0	0.054
693.3	0.114	666.3	0.075	652.3	0.040
726.9	0.086	703.6	0.066	689.7	0.040
774.6	0.103	745.3	0.075	728.1	0.046
897.1	0.087	870.4	0.052	856.9	0.029
939.9	0.087	910.1	0.058	891.2	0.034
944.1	0.075	917.8	0.052	903.4	0.031

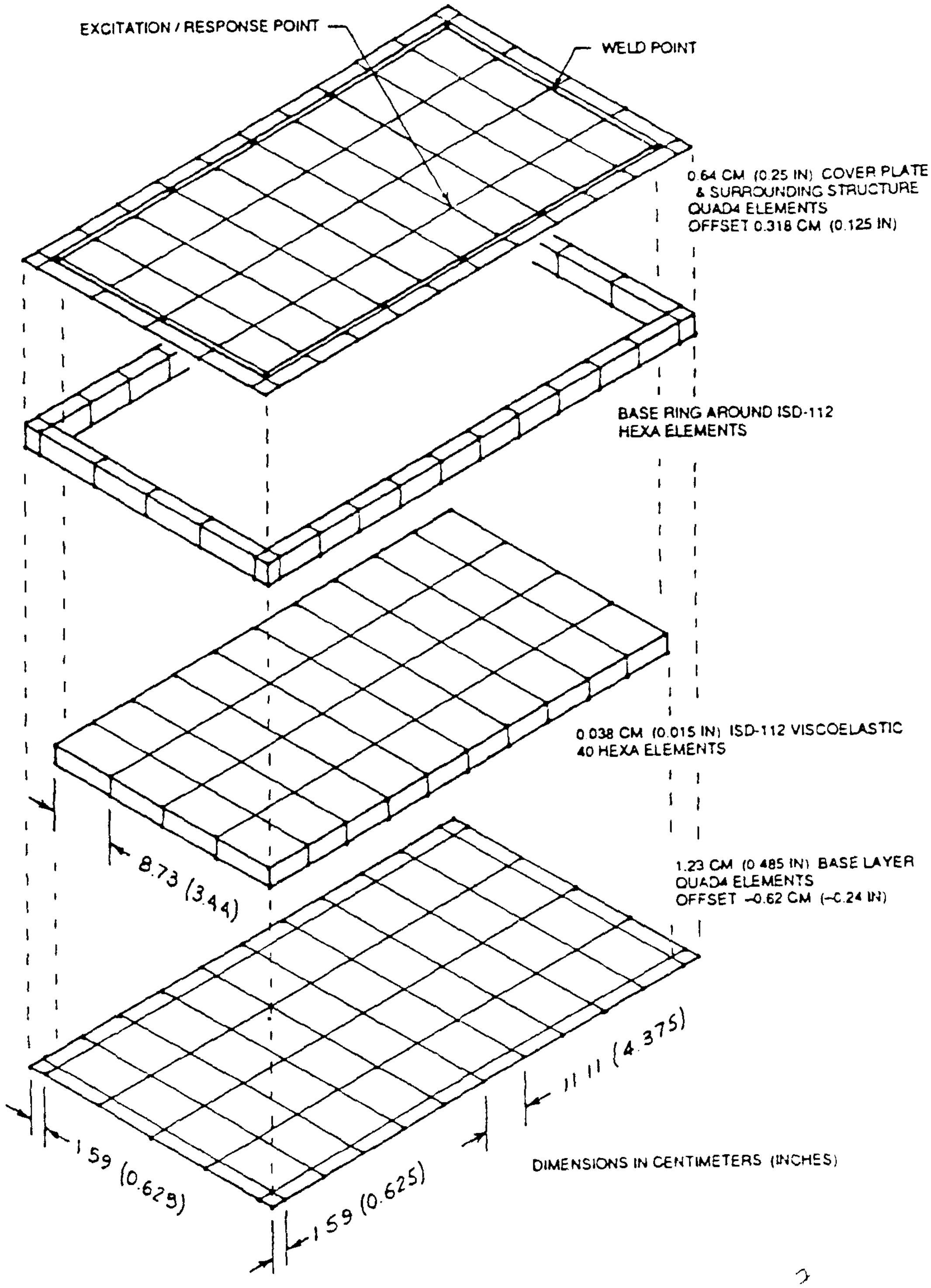

Figure 4.1. Finite Element Representation of the Pocket Plate Configuration.

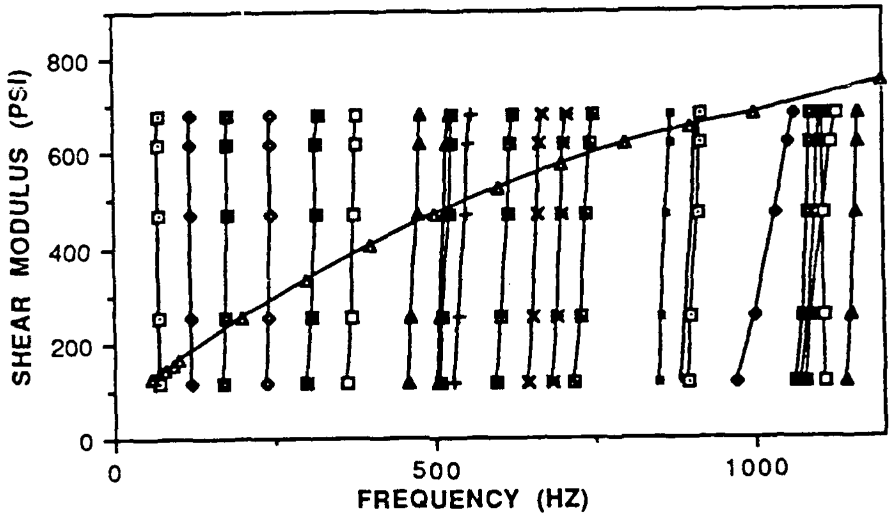

Figure 4.2. Interpolation of the Modal Frequencies fo. the Spot Welded Floating Element Configuration

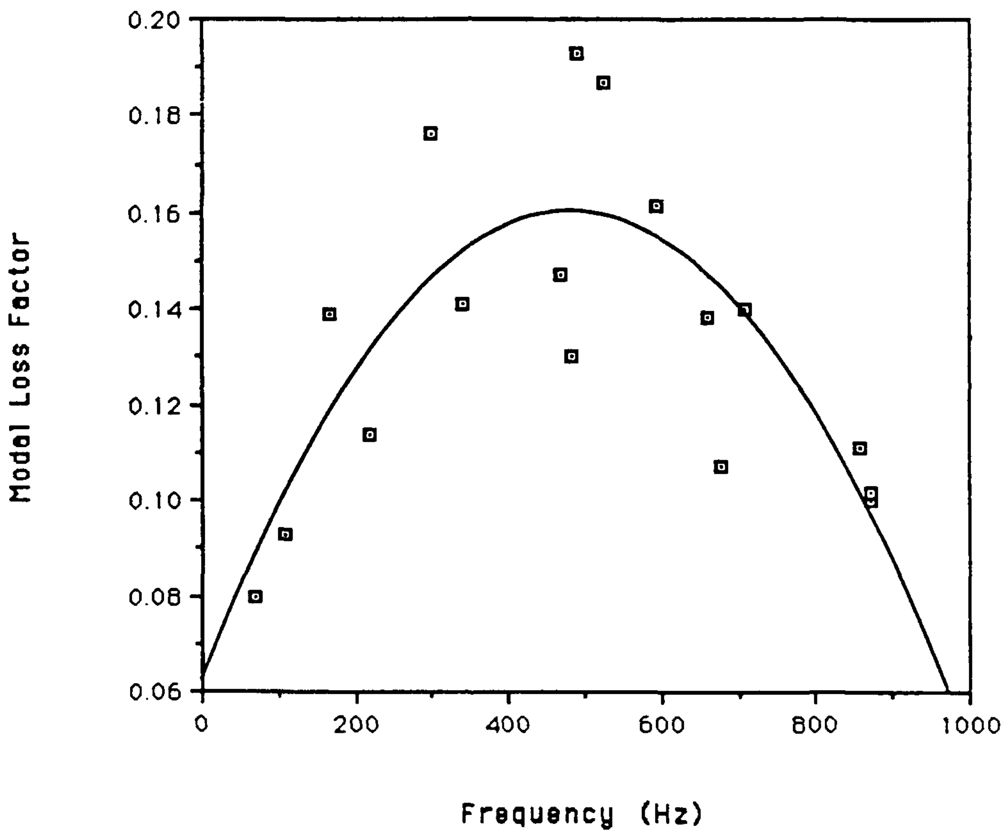

Figure 4.3. Estimated Modal Loss Factors for the Spot Welded Floating Element Configuration with the Curve Fit Used for the MSC/NASTRAN Damping Table.

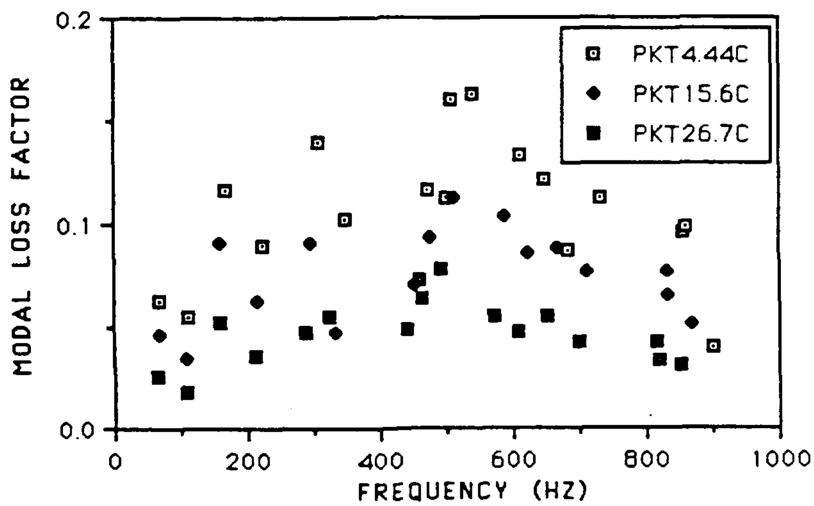

Figure 4.4. Estimated Modal Loss Factor for Spot Welded Pocket Plate at 4.44/15.6/26.7 °C.

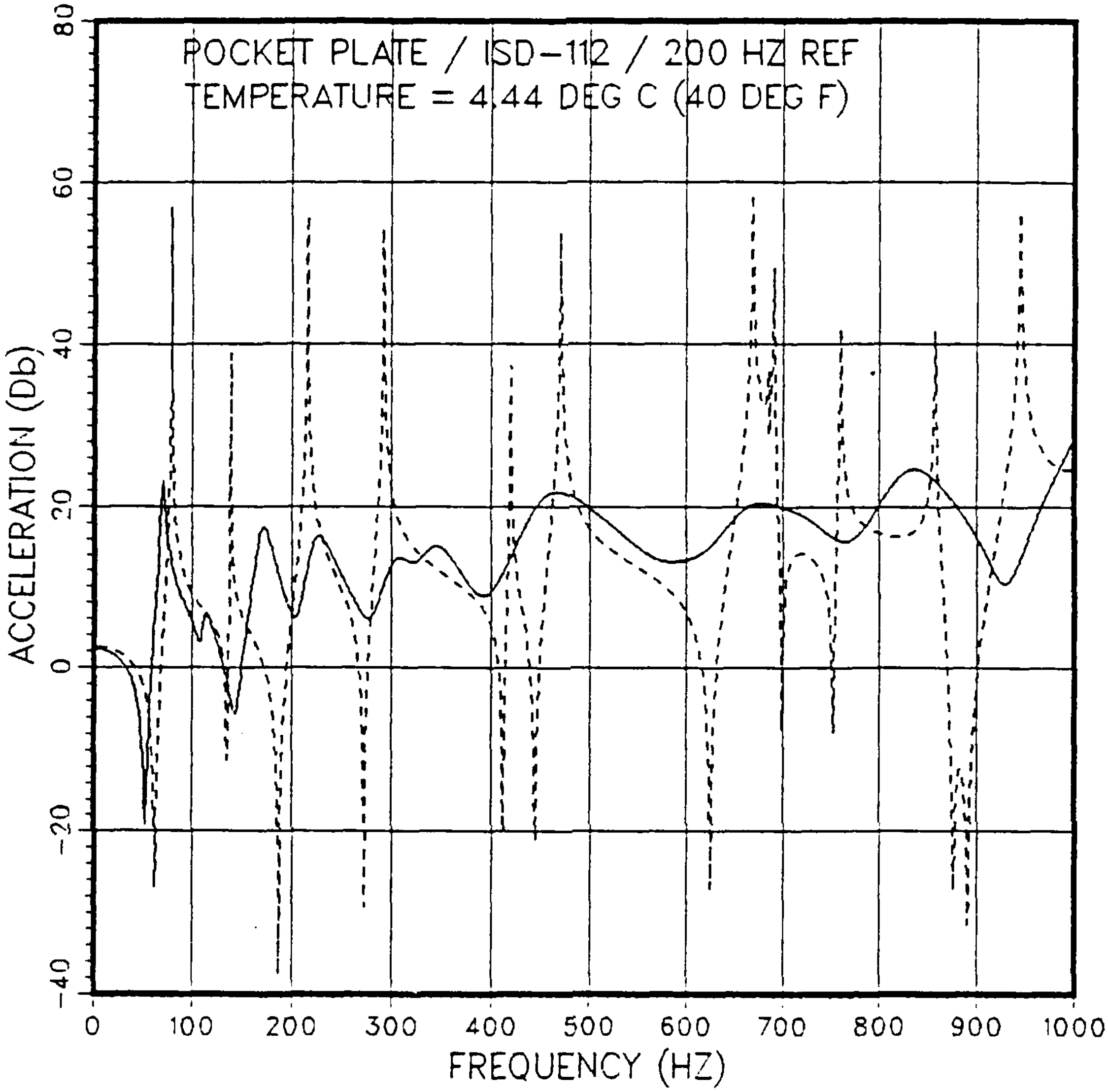

Figure 4.5. Calculated Frequency Response of the Spot Welded Pocket Plate at 4.44 °C.

[- - - - : reference plate , ——— : spot welded pocket plate]

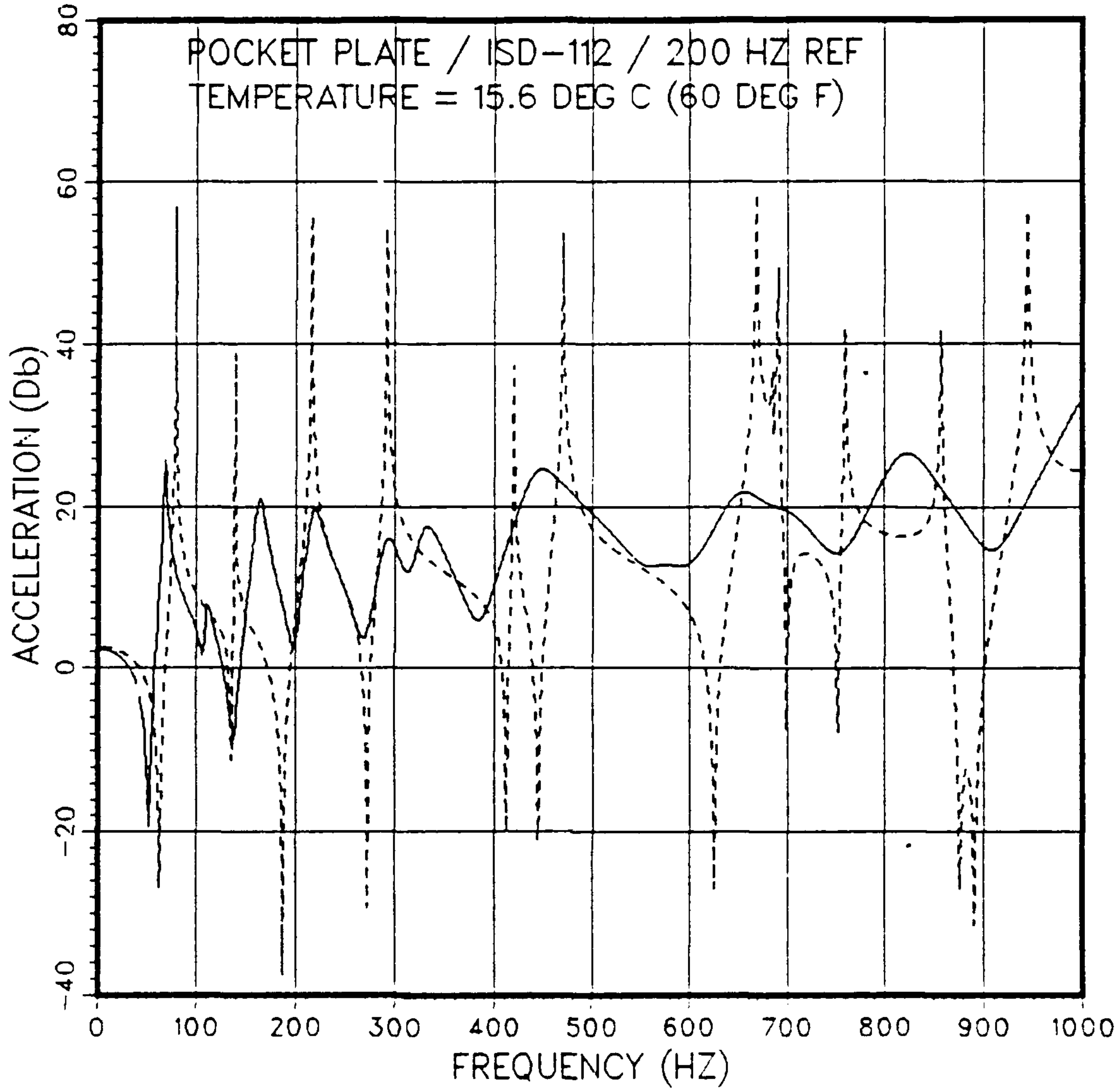

Figure 4.6. Calculated Frequency Response of the Spot Welded Pocket Plate at 15.6 °C.

[- - - - : reference plate , ——— : spot welded pocket plate]

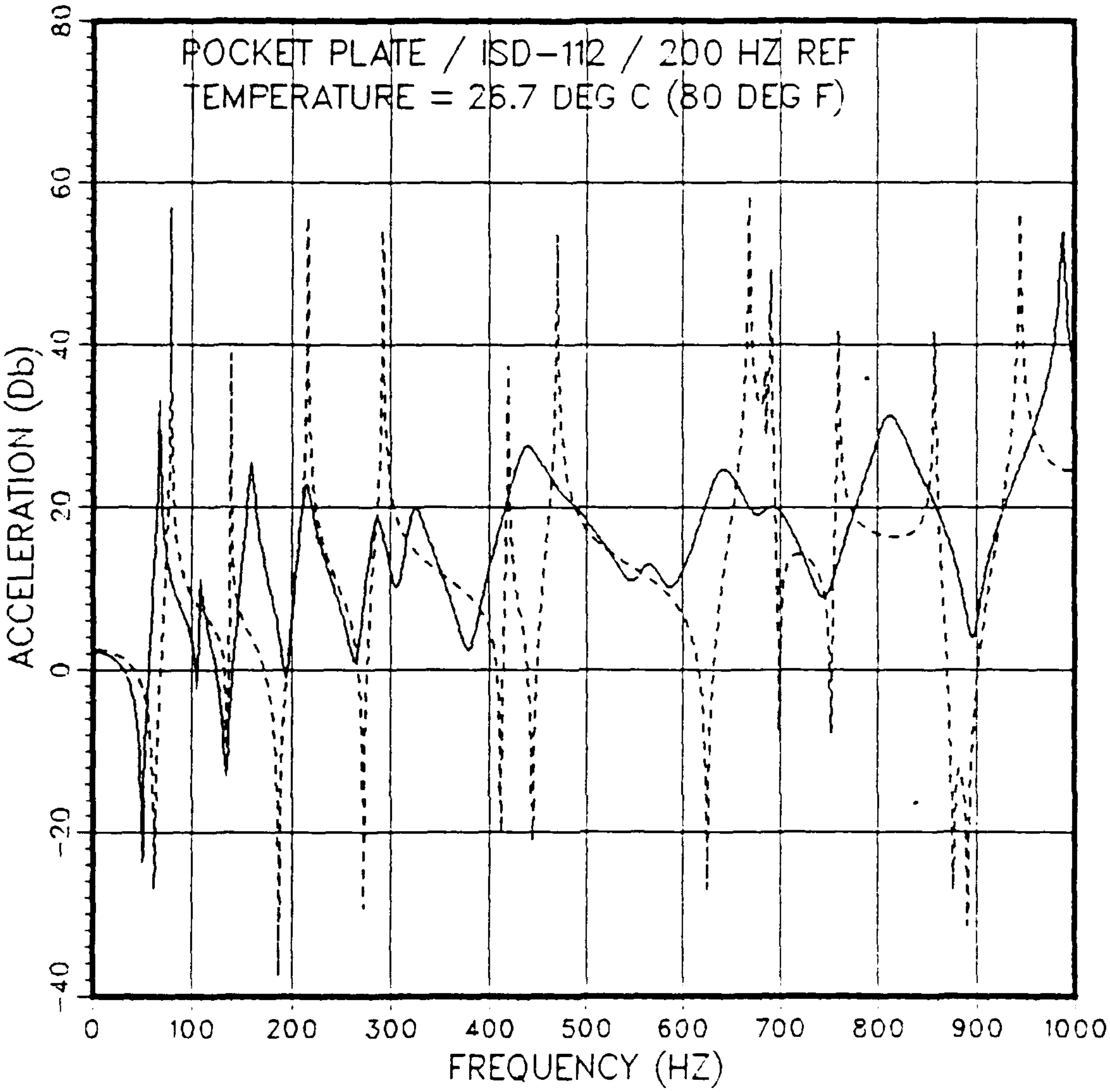

Figure 4.7. Calculated Frequency Response of the Spot Welded Pocket Plate at 26.7 °C.

[- - - - : reference plate , ——— : spot welded pocket plate]

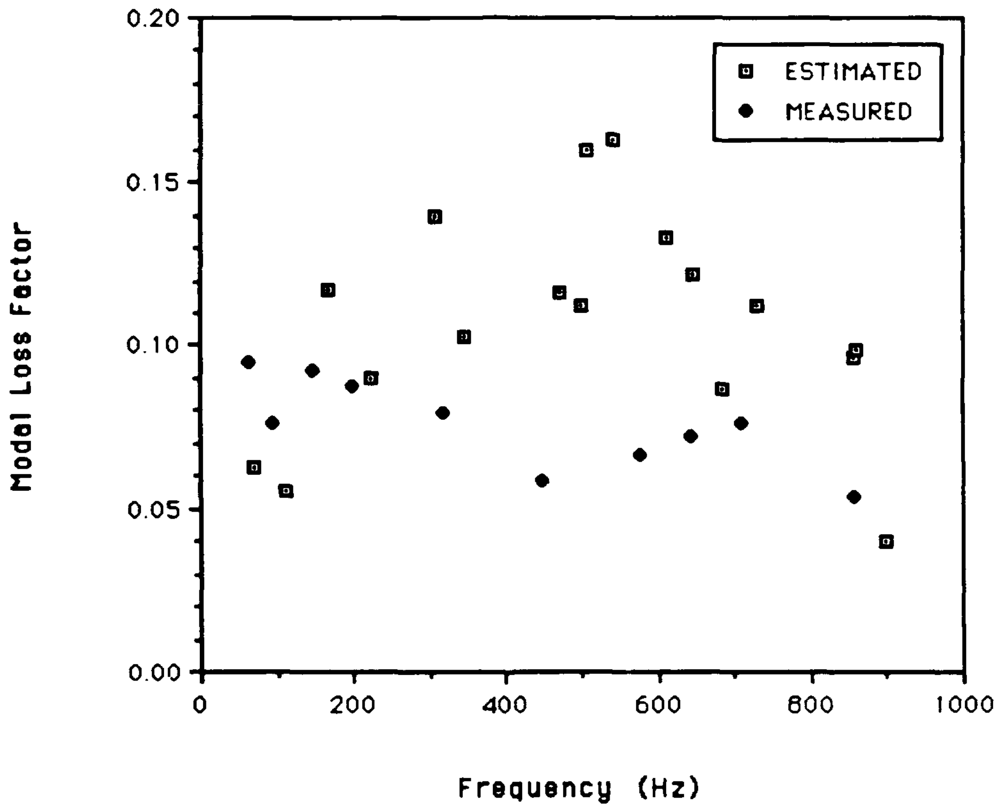

Figure 4.8. Comparison of Estimated and Measured Modal Loss Factors for Spot Welded Pocket Plate at 4.44 °C.

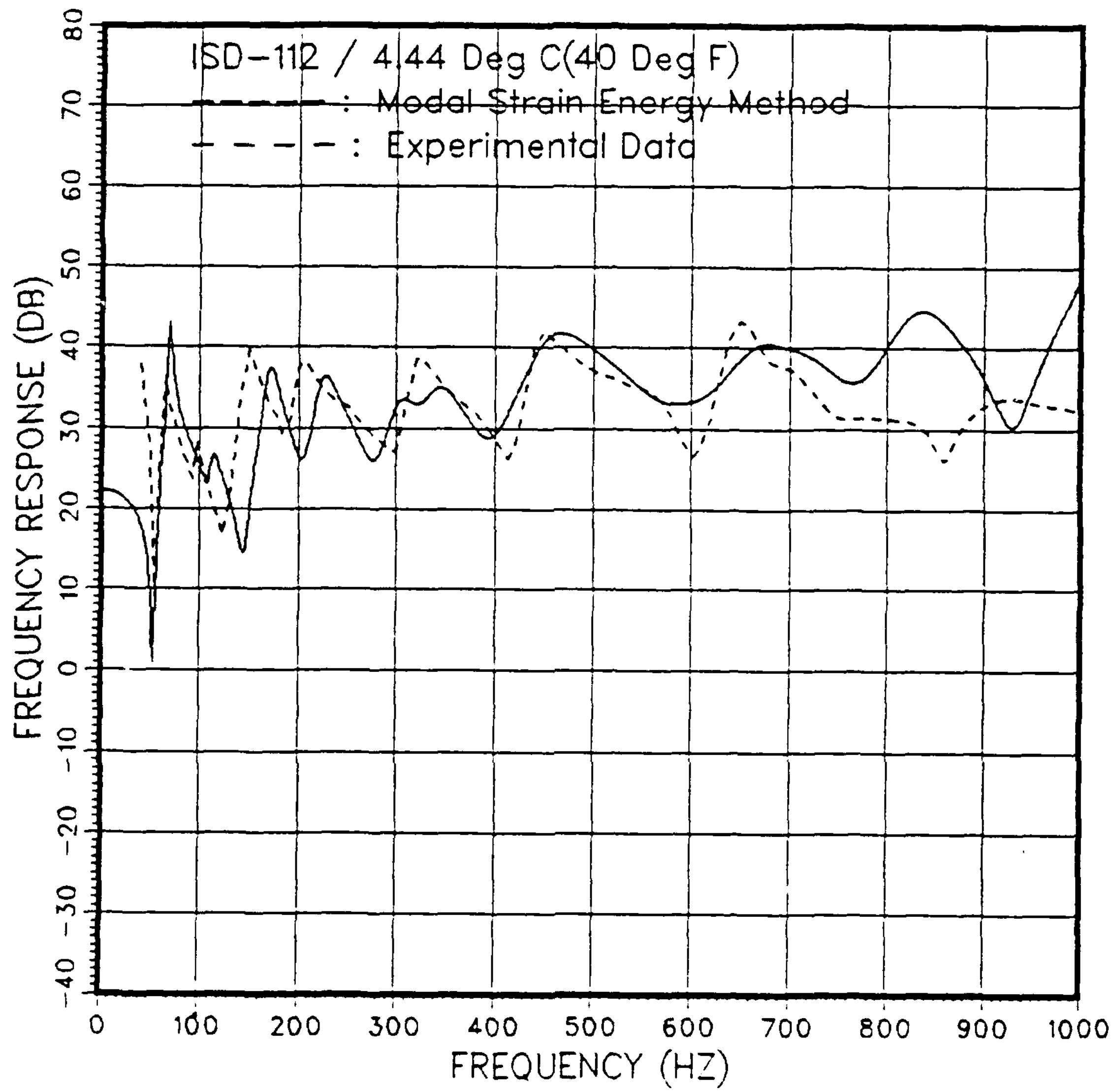

Figure 4.9. Comparison of Estimated and Measured Frequency Response for the Spot Welded Pocket Plate at 4.44 °C.

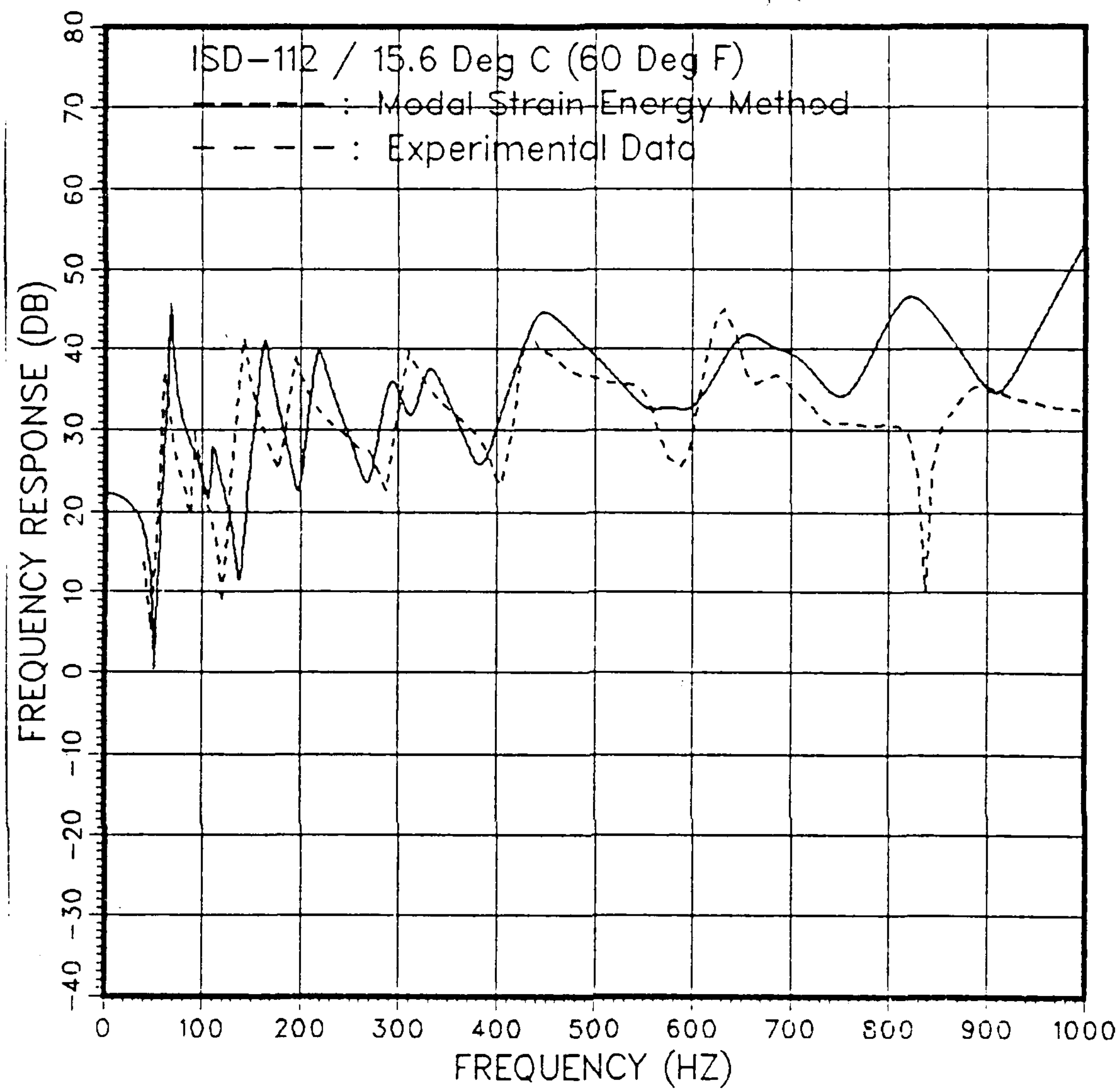

Figure 4.10. Comparison of Estimated and Measured Frequency Response for the Spot Welded Pocket Plate at 15.6 °C.

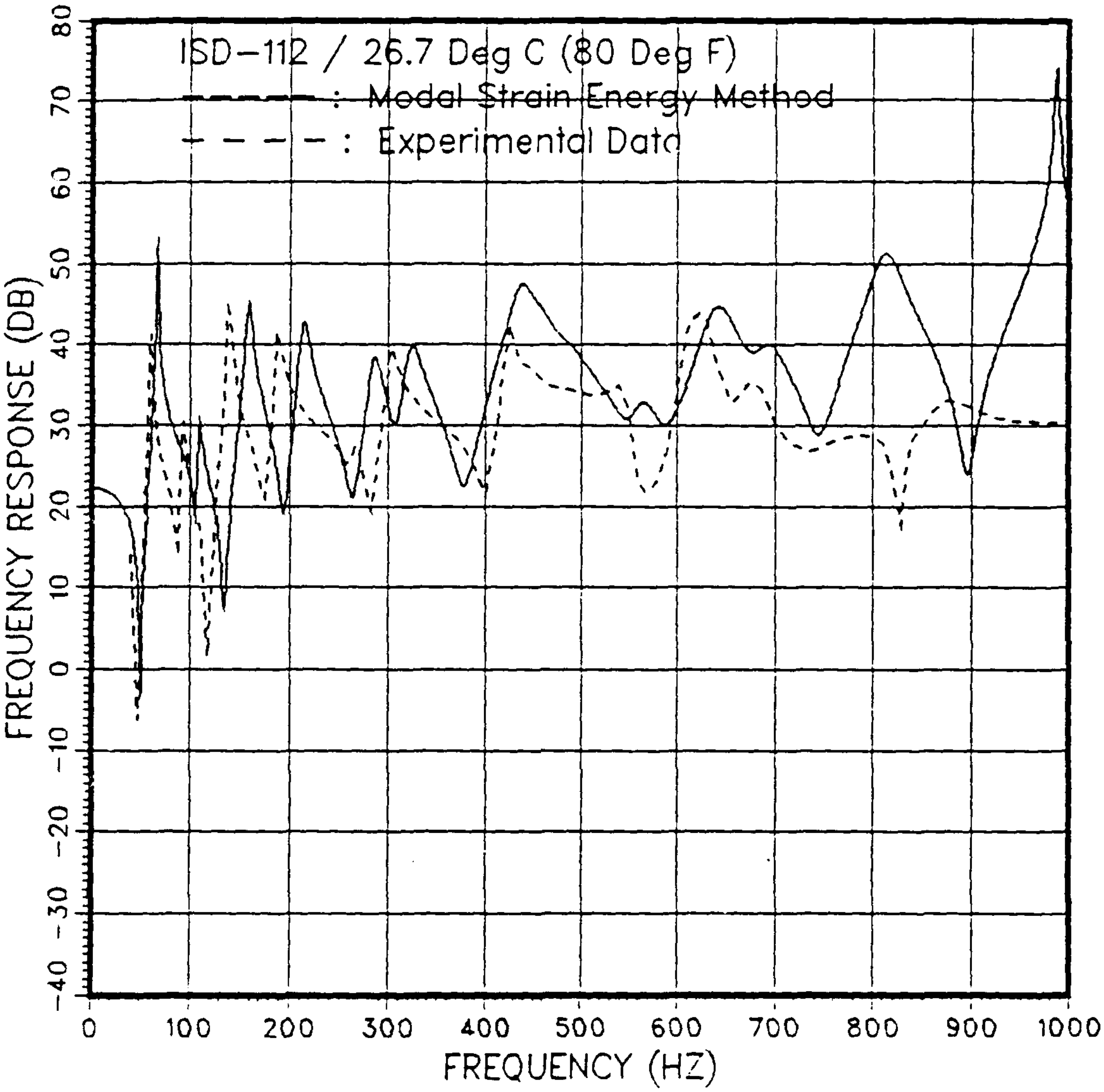

Figure 4.11. Comparison of Estimated and Measured Frequency Response for the Spot Welded Pocket Plate at 26.7 °C.

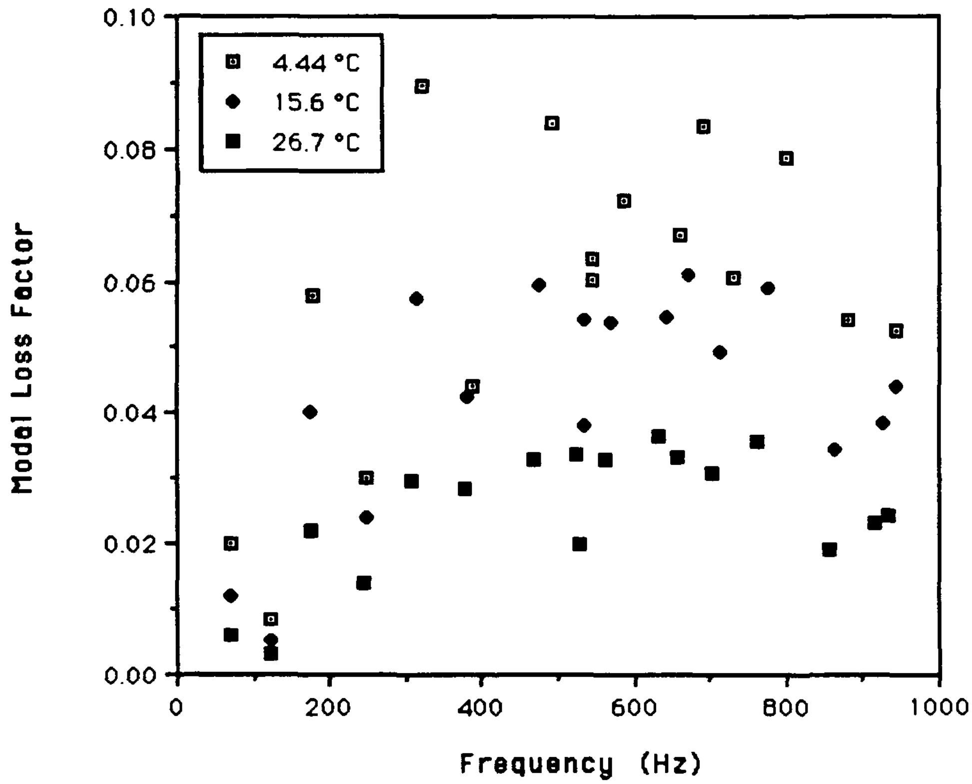

Figure 4.12 Estimated Modal Loss Factor for Line Welded Pocket Plate at 4.44/15.6/26.7 °C.

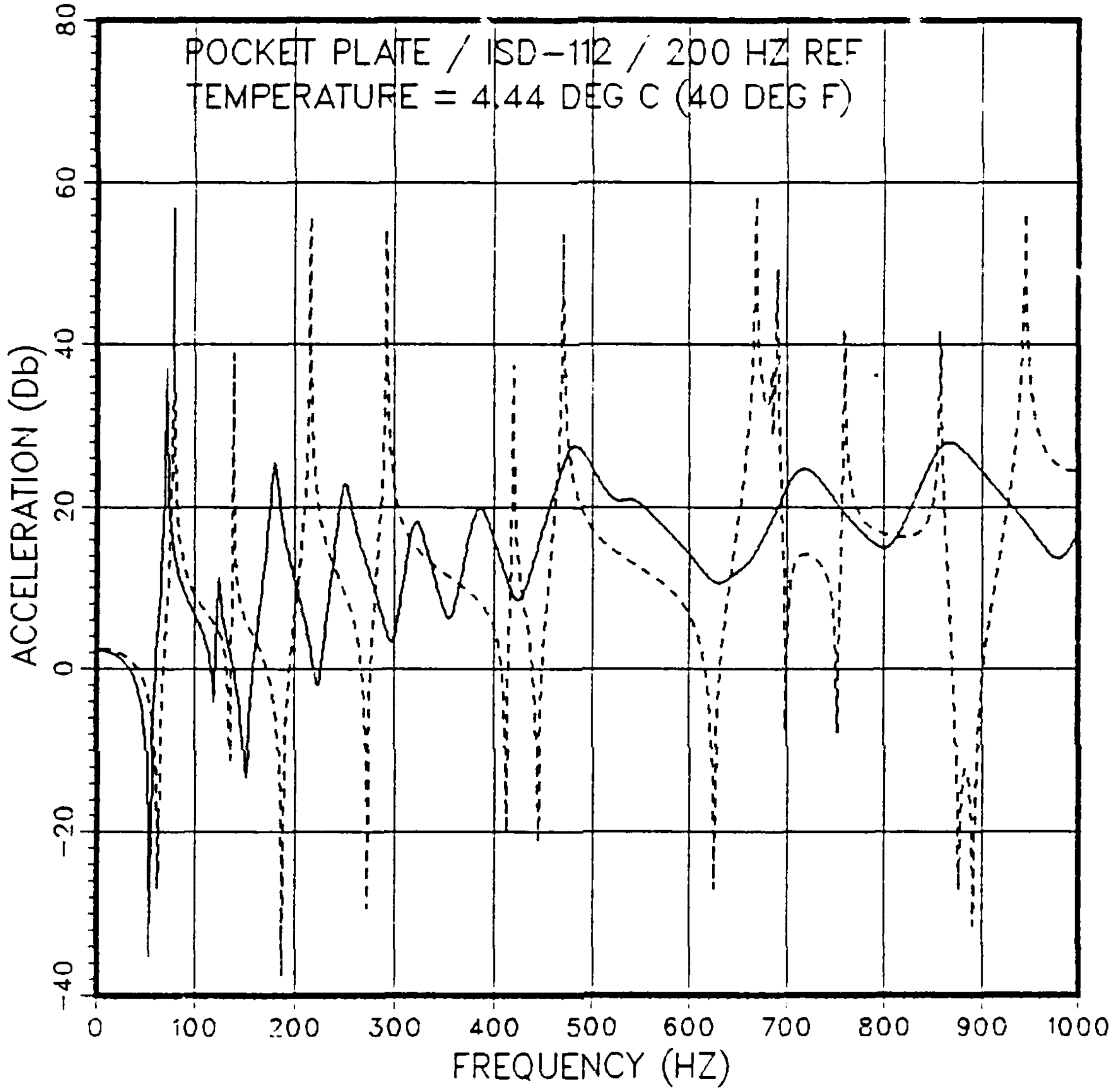

Figure 4.13. Calculated Modal Frequency Response of the Line Welded Pocket Plate at 4.44 °C.

[- - - - : reference plate , —— : line welded pocket plate]

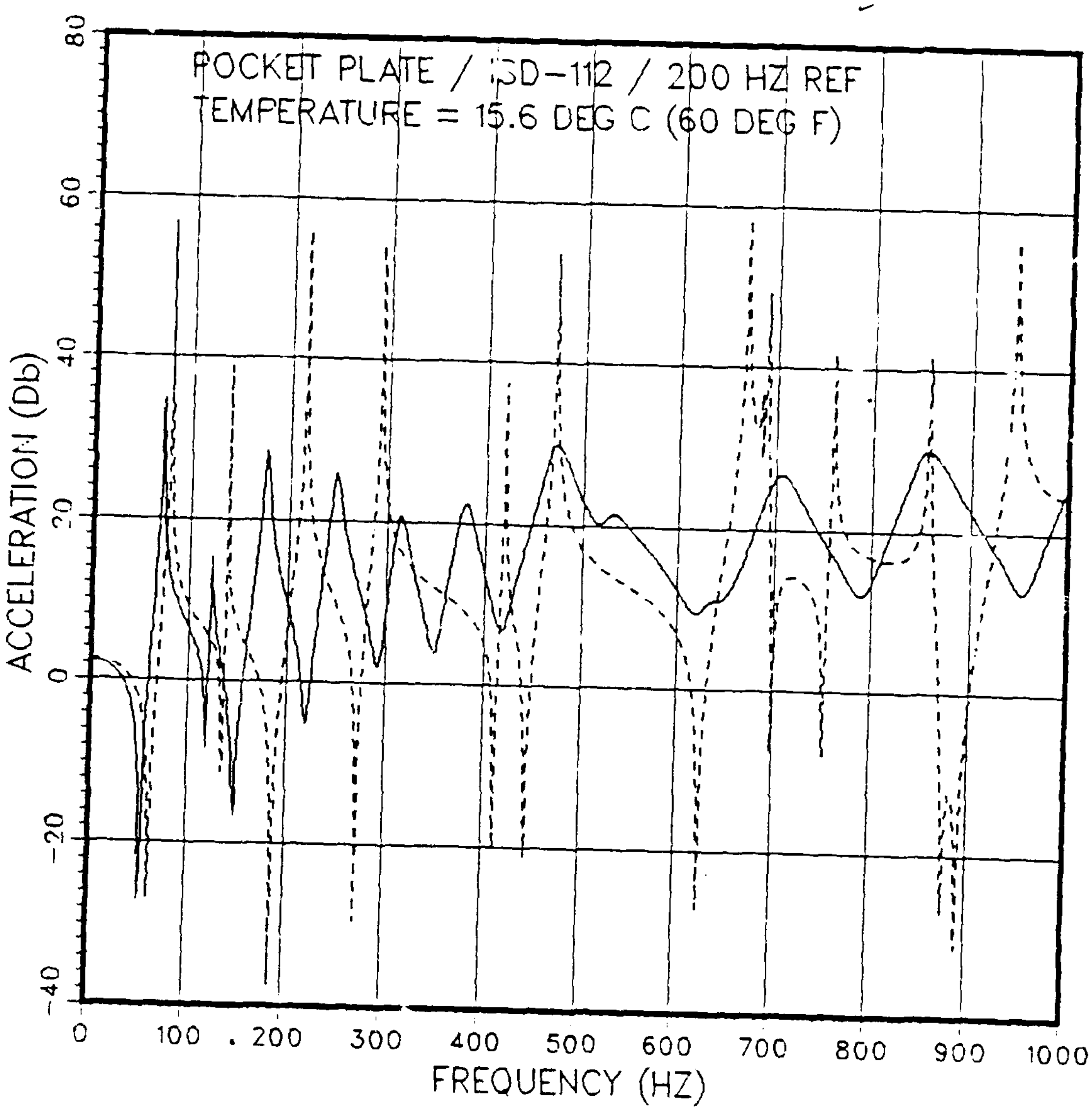

Figure 4.14. Calculated Modal Frequency Response of the Line Welded Pocket Plate at 15.6 °C.

[- - - - : reference plate , —— : line welded pocket plate]

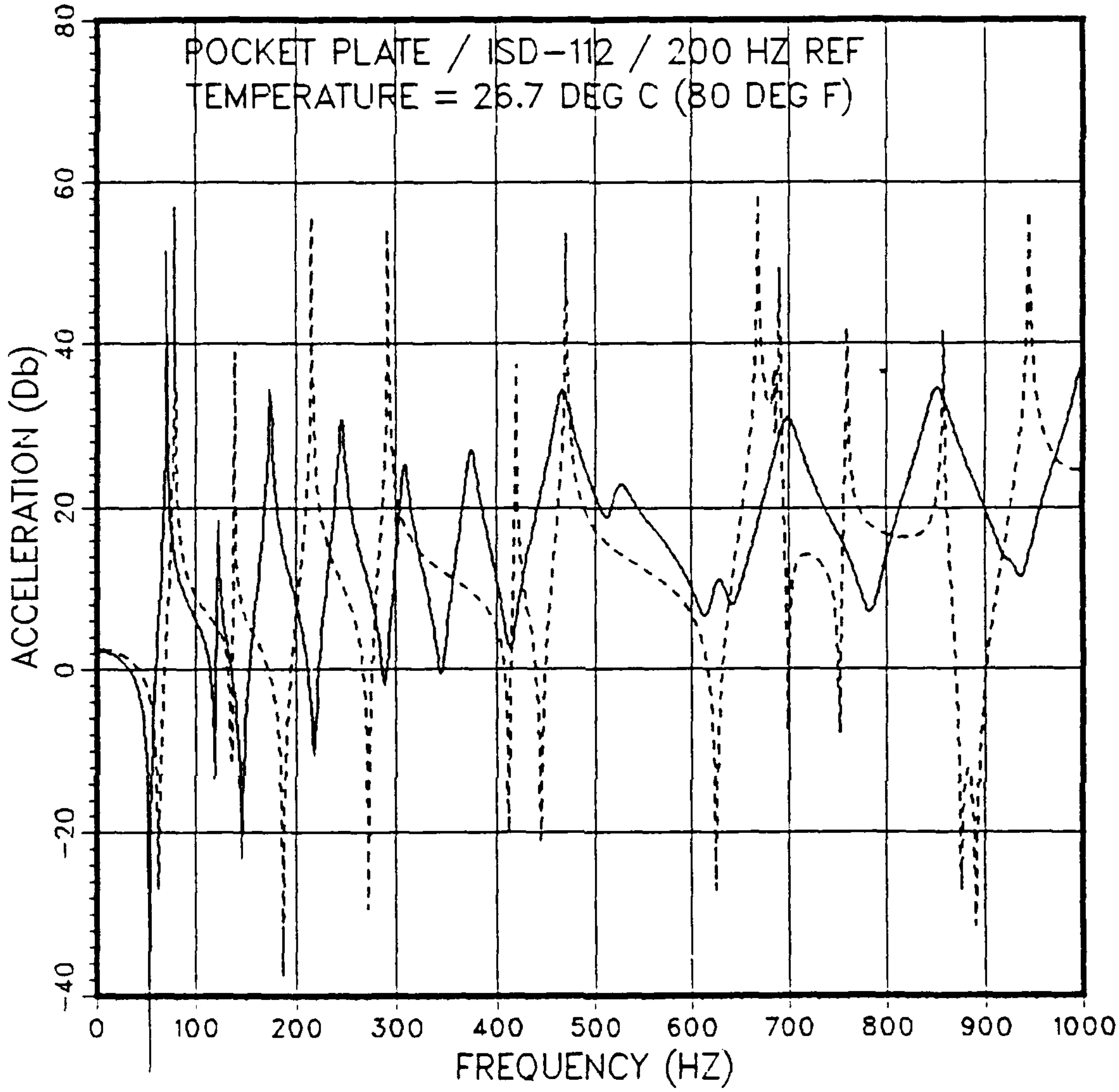

Figure 4.15. Calculated Modal Frequency Response of the Line Welded Pocket Plate at 26.7 °C.

[- - - - : reference plate , ——— : line welded pocket plate]

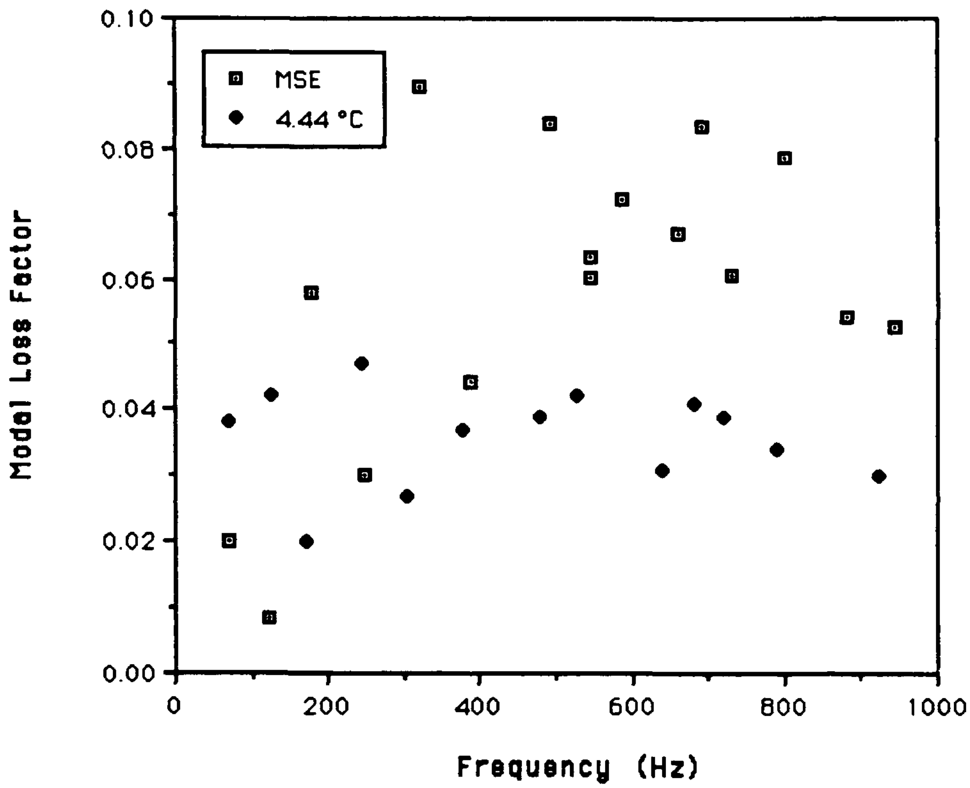

Figure 4.16. Comparison of Estimated and Measured Modal Loss Factors for Line Welded Pocket Plate at 4.44 °C.

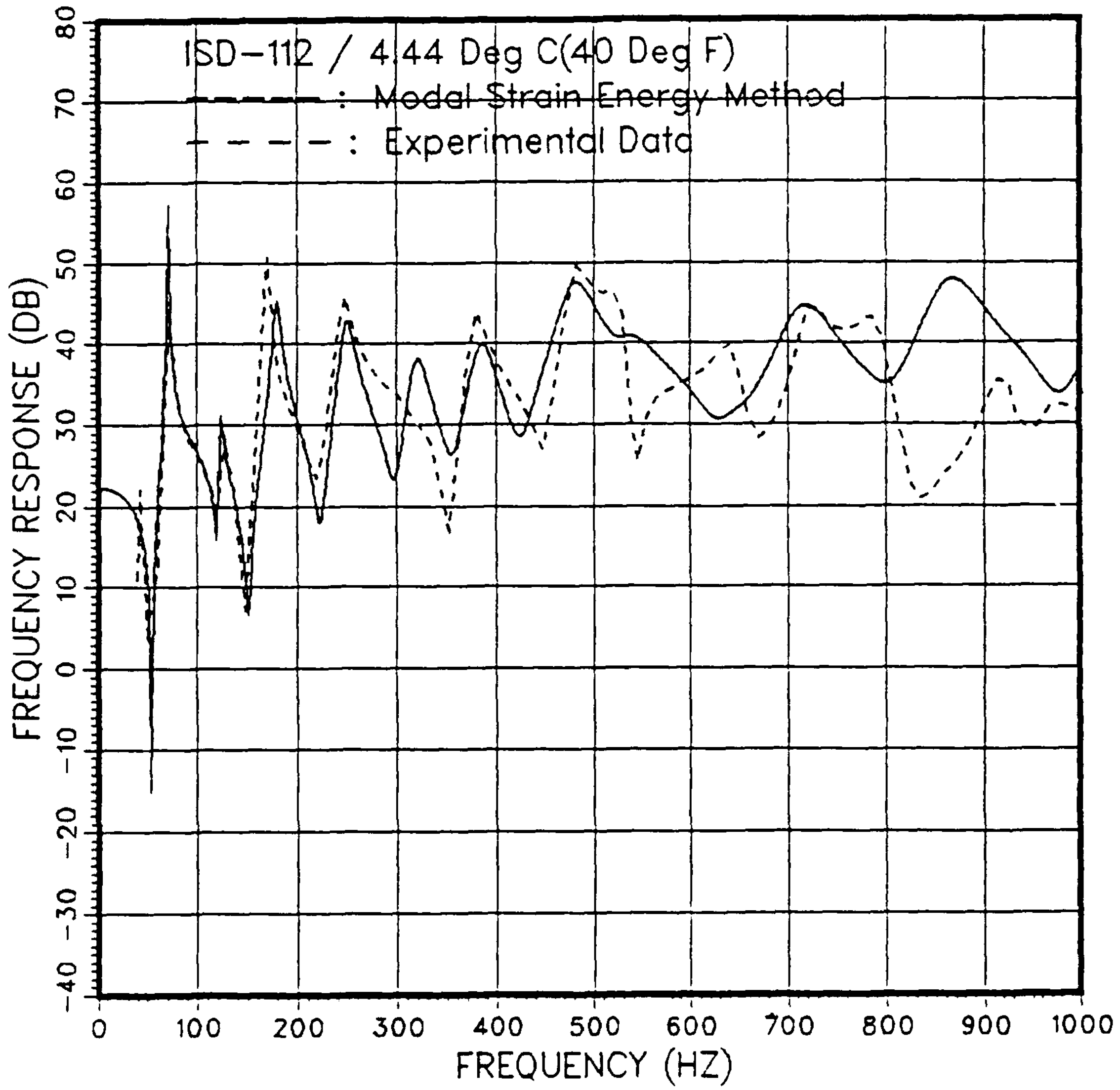

Figure 4.17. Comparison of Estimated and Measured Frequency Response for the Line Welded Pocket Plate at 4.44 °C.

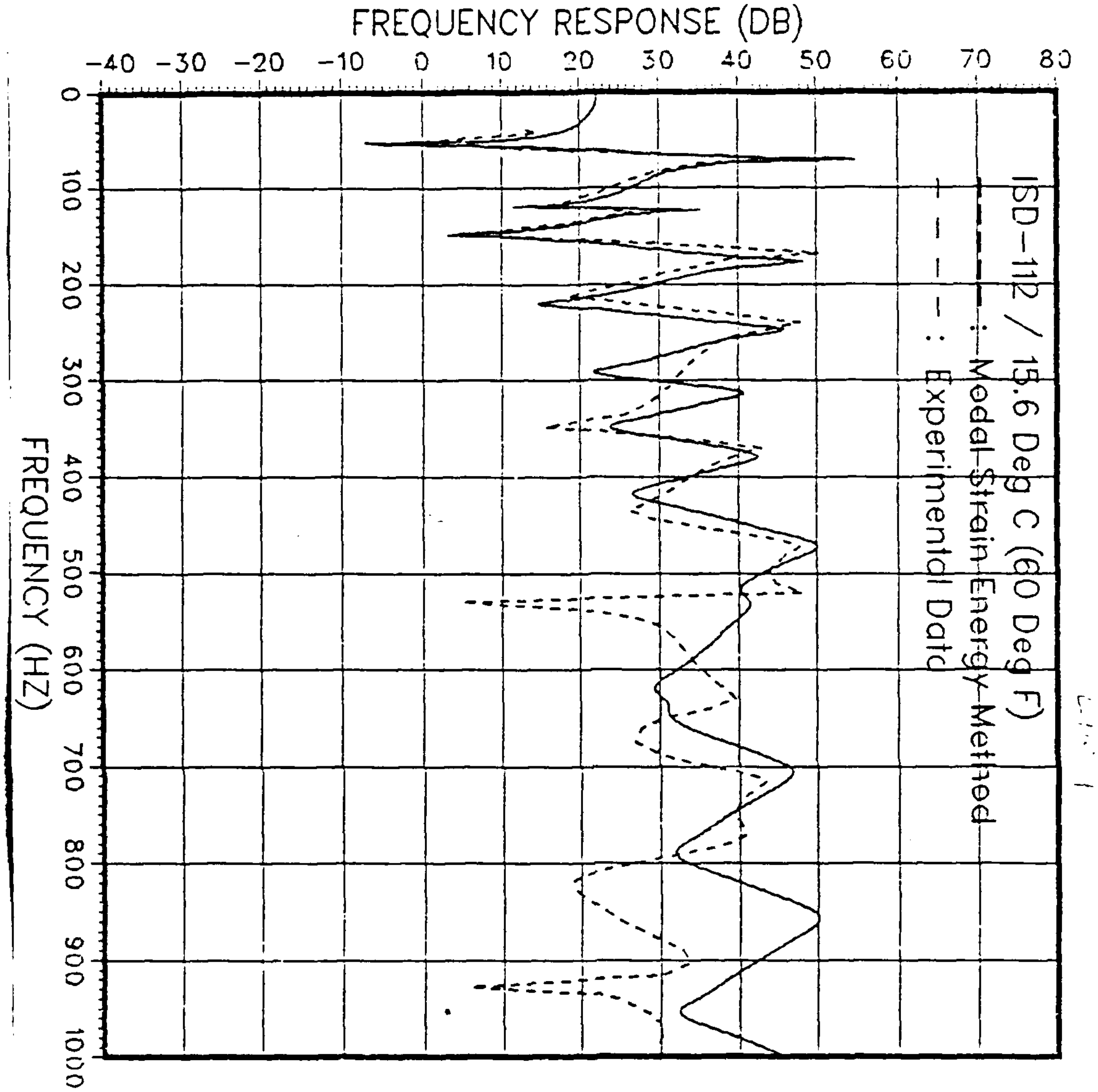

Figure 4.18. Comparison of Estimated and Measured Frequency Response for the Line Welded Pocket Plate at 15.6 °C.

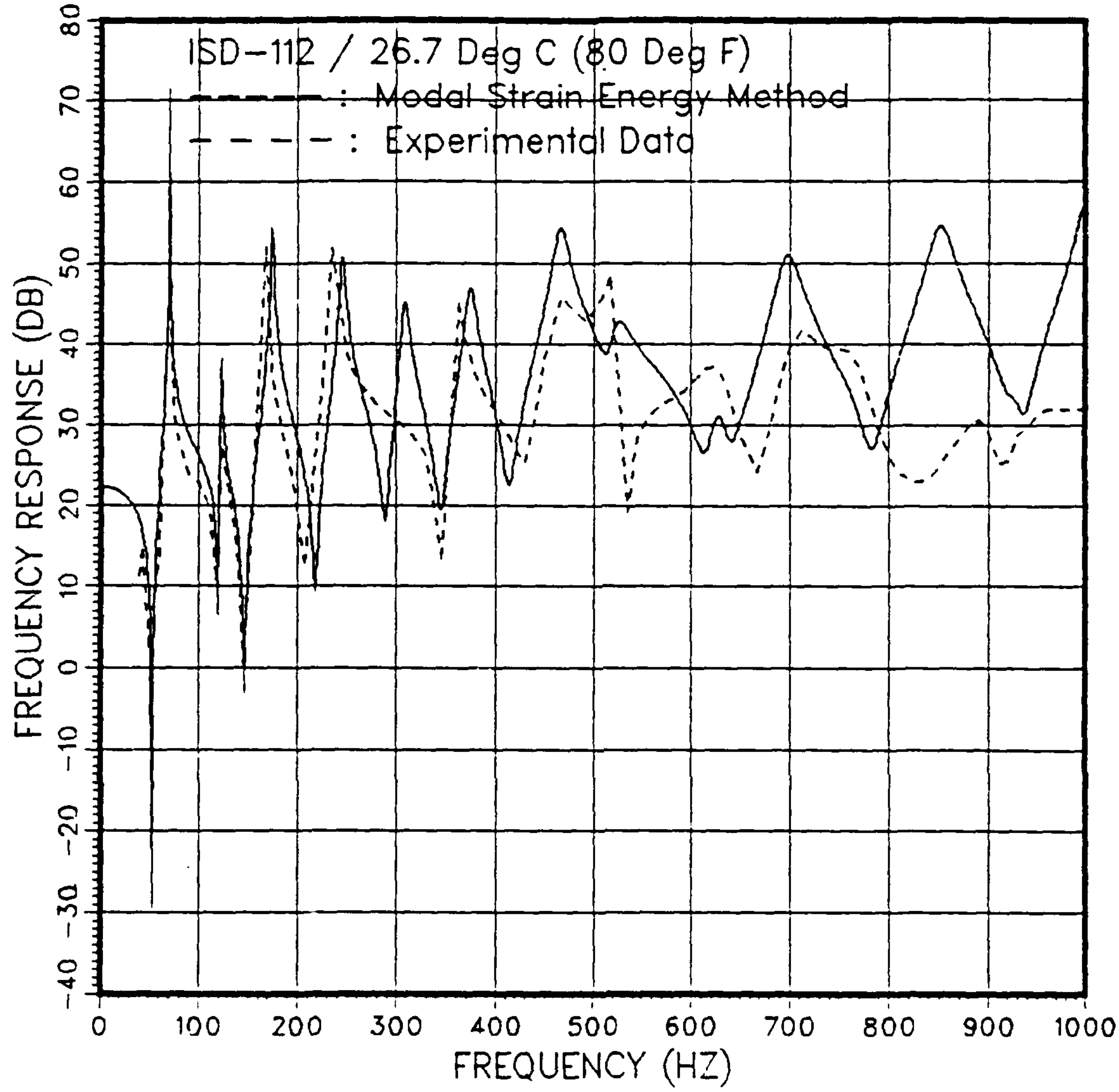

Figure 4.19. Comparison of Estimated and Measured Frequency Response for the Line Welded Pocket Plate at 26.7 °C.

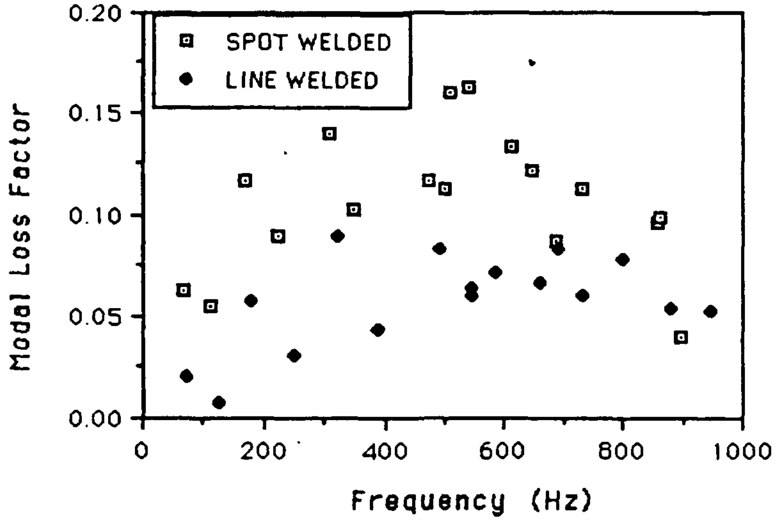

Figure 4.20. Comparison of Estimated Modal Loss Factor for Spot and Line Welded Pocket Plate at 4.44 °C.

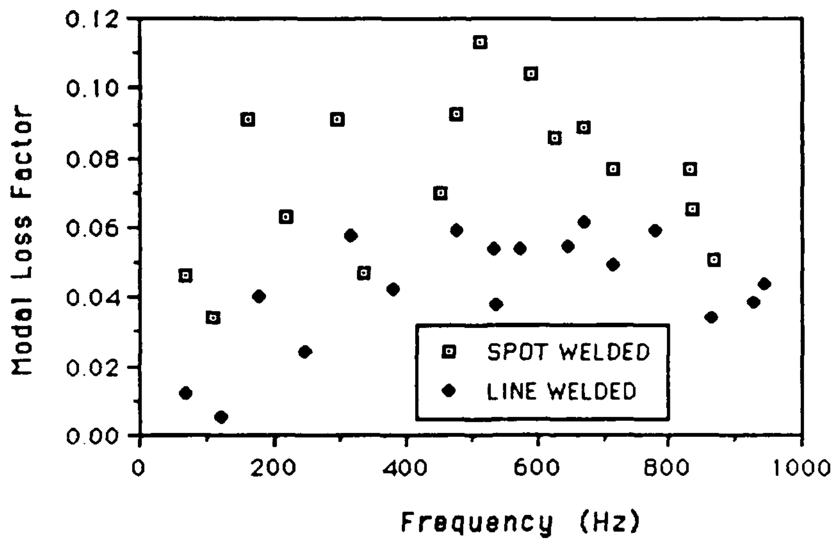

Figure 4.21. Comparison of Estimated Modal Loss Factor for Spot and Line Welded Pocket Plate at 15.6 °C.

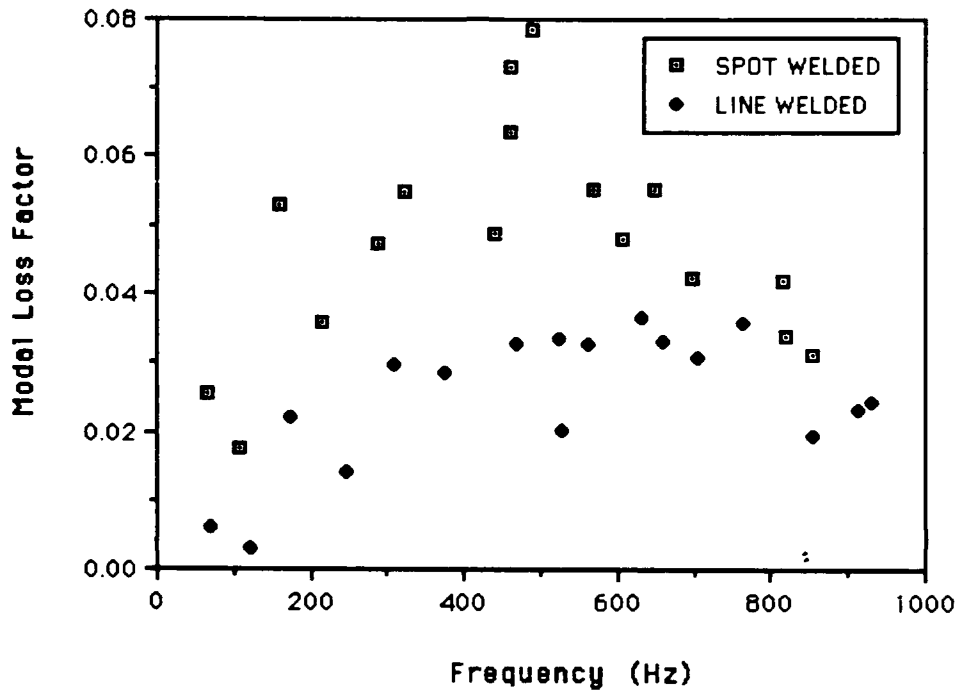

Figure 4.22. Comparison of Estimated Modal Loss Factor for Spot and Line Welded Pocket Plate at 26.7 °C.

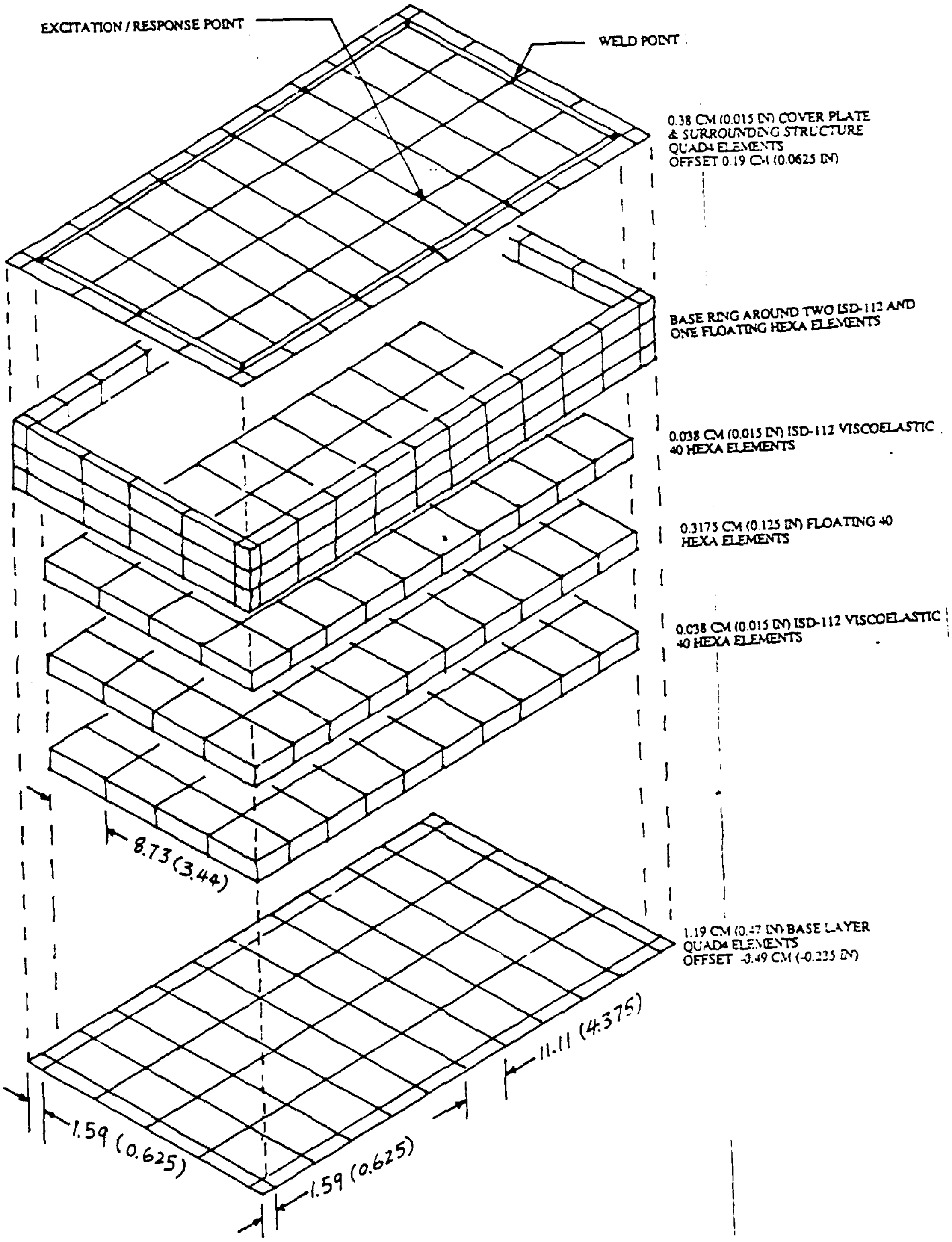

Figure 4.23. Finite Element Representation of the Floating Element Plate Configuration.

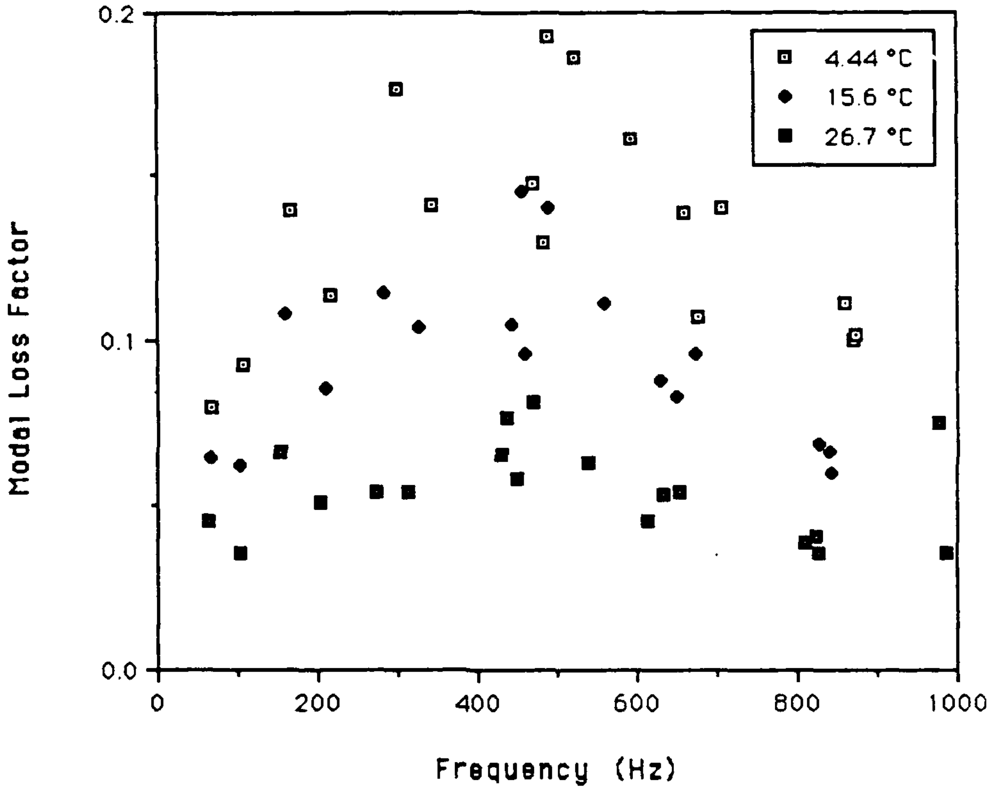

Figure 4.24. Estimated Modal Loss Factor for Spot Welded Floating Element Plate at 4.44/15.6/26.7 °C.

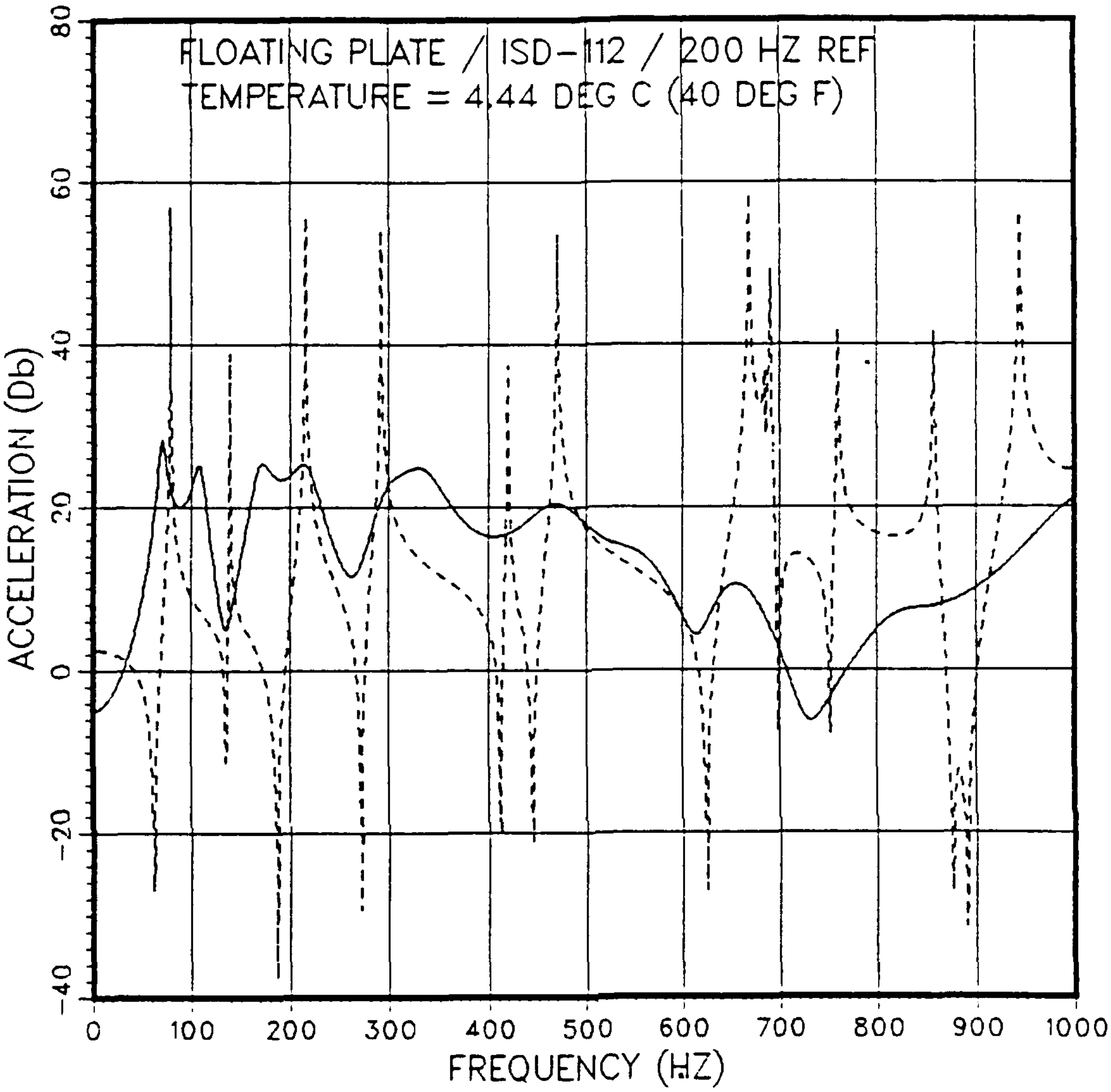

Figure 4.25. Calculated Modal Frequency Response of the Spot Welded Floating Element Configuration Using NASTRAN.

[- - - - : reference plate , ——— : spot welded floating element]

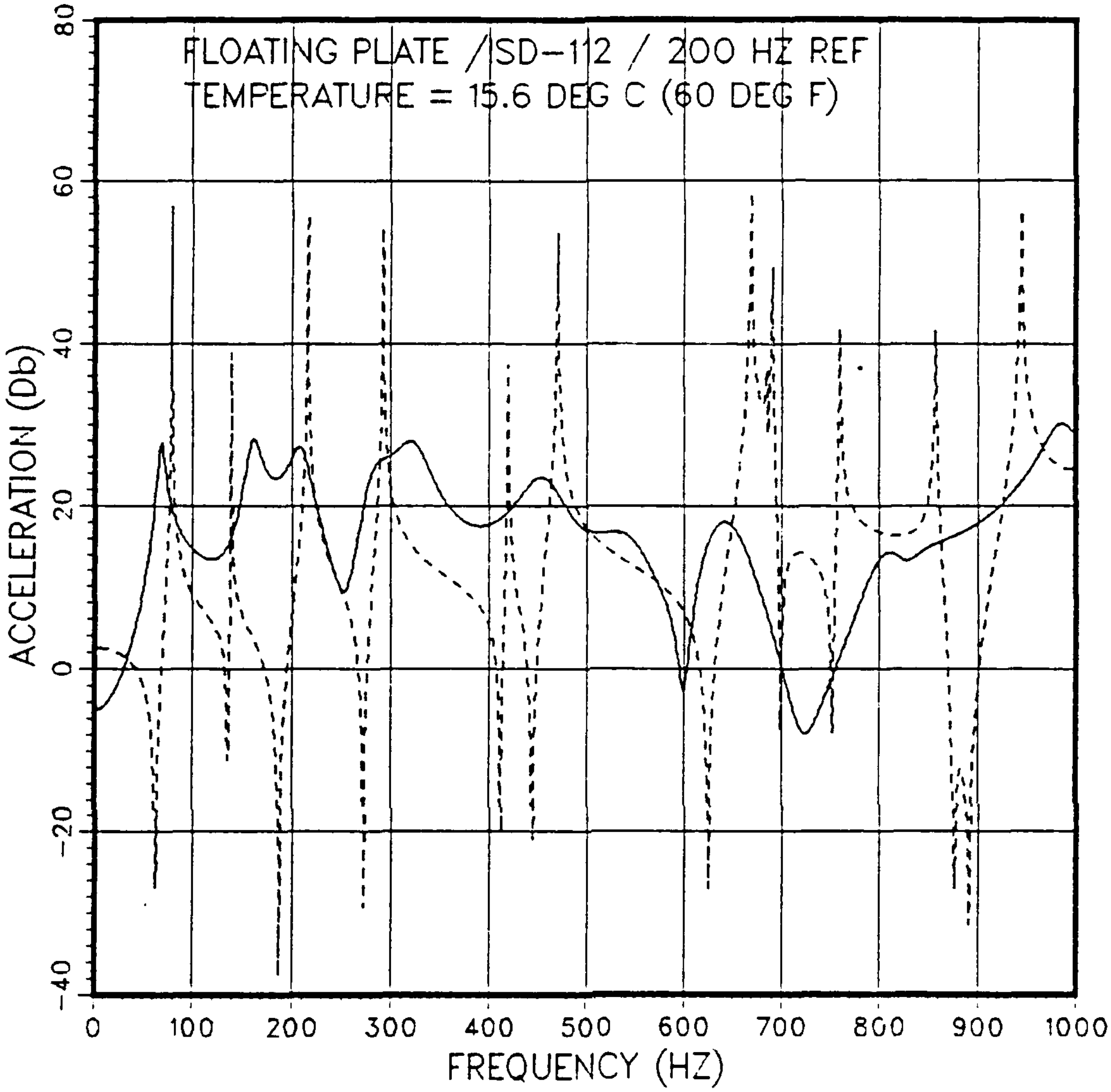

Figure 4.26. Calculated Modal Frequency Response of the Spot Welded Floating Element Configuration Using NASTRAN.

[- - - - : reference plate , —— : spot welded floating element]

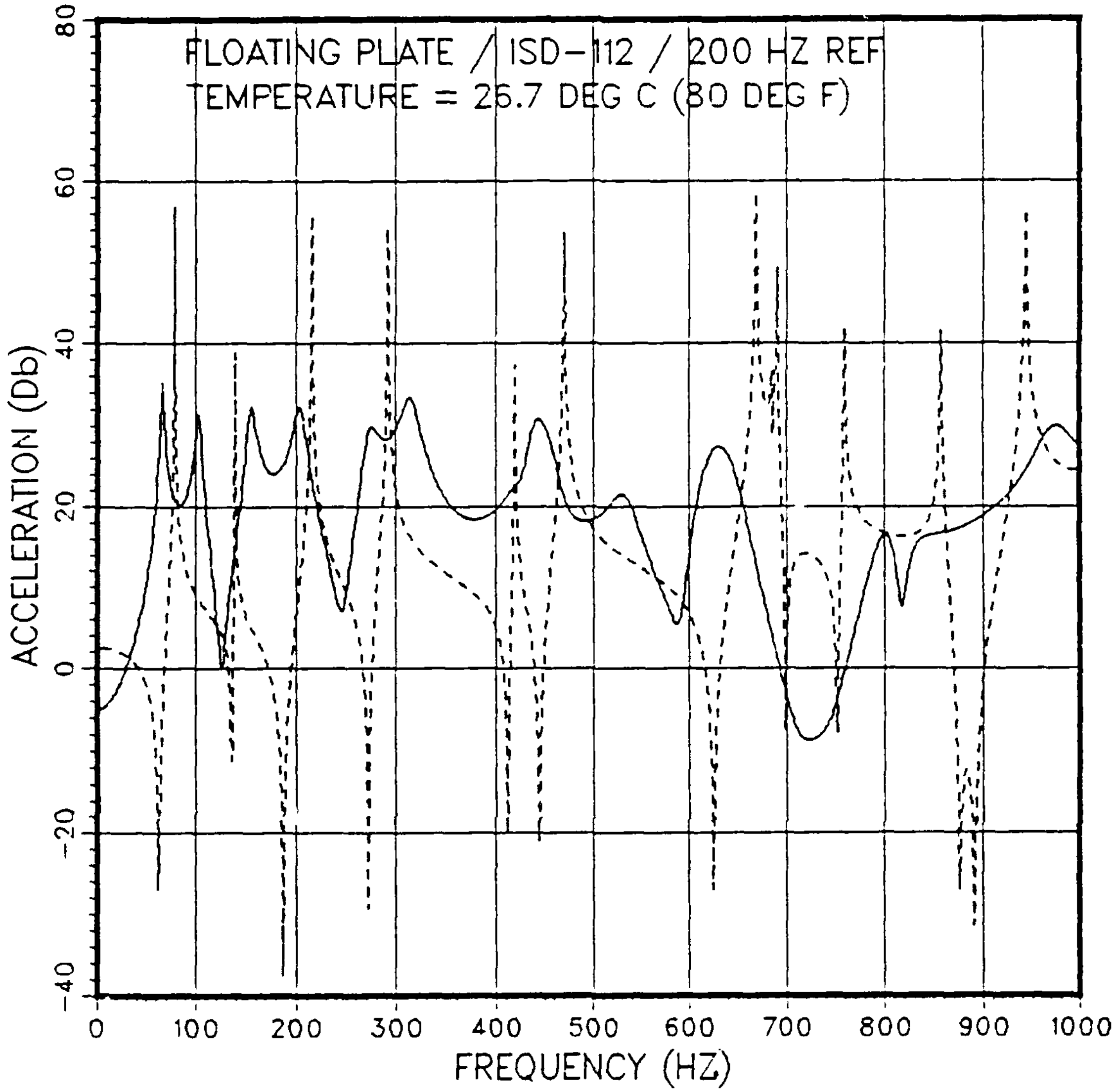

Figure 4.27. Calculated Modal Frequency Response of the Spot Welded Floating Element Configuration Using NASTRAN.

[- - - - : reference plate , ——— : spot welded floating element]

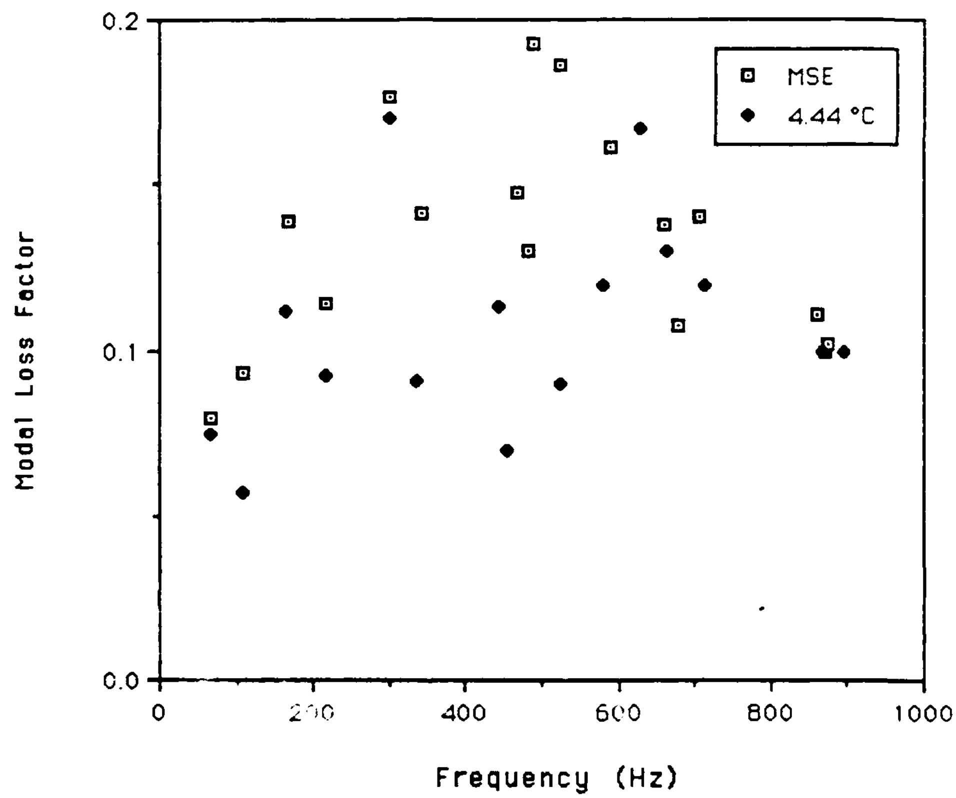

Figure 4.28. Comparison of Estimated and Measured Modal Loss Factors for Spot Welded Floating Element Configuration.

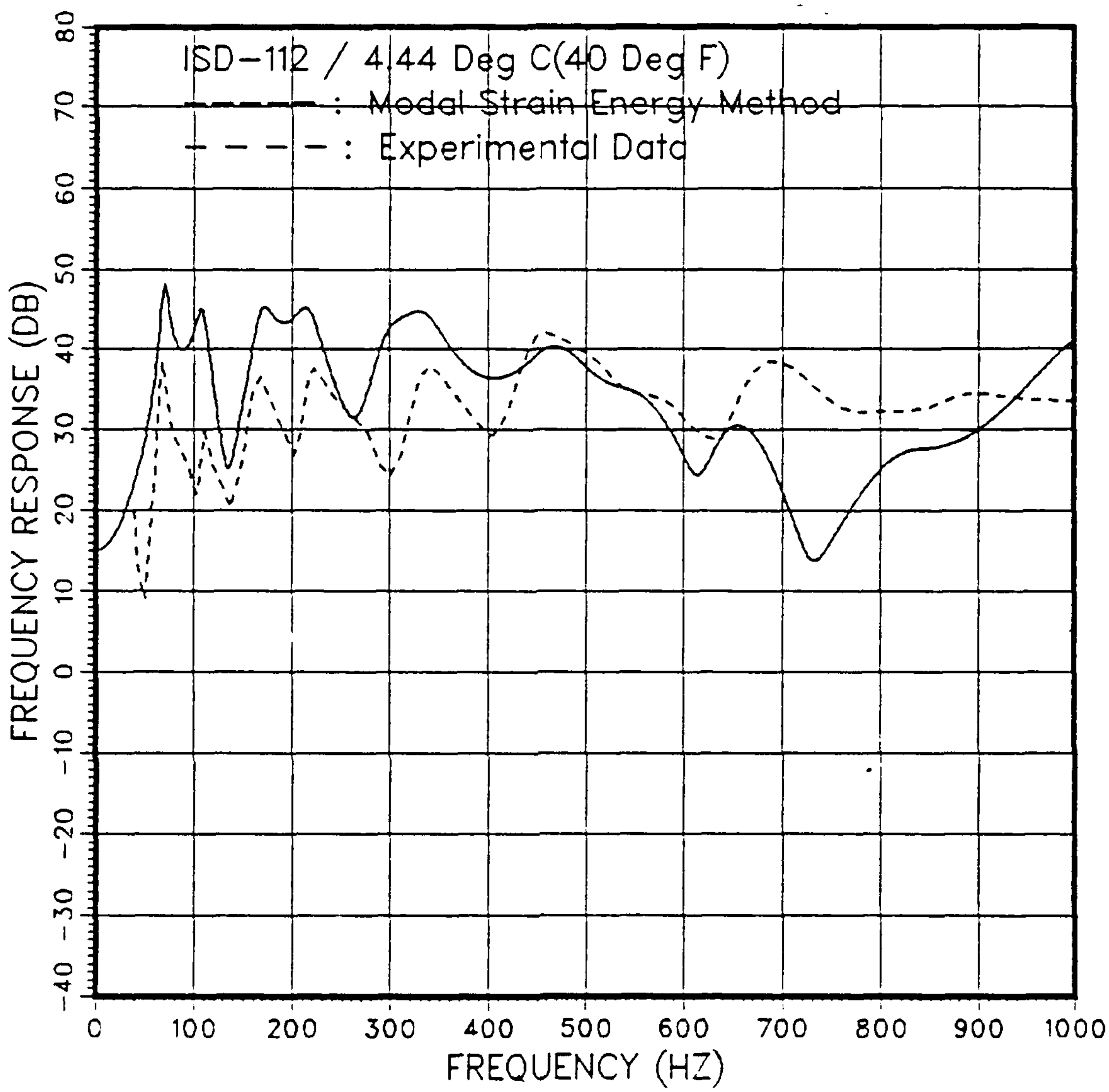

Figure 4.29. Comparison of Estimated and Measured Frequency Response for the Spot Welded Floating Element Configuration.

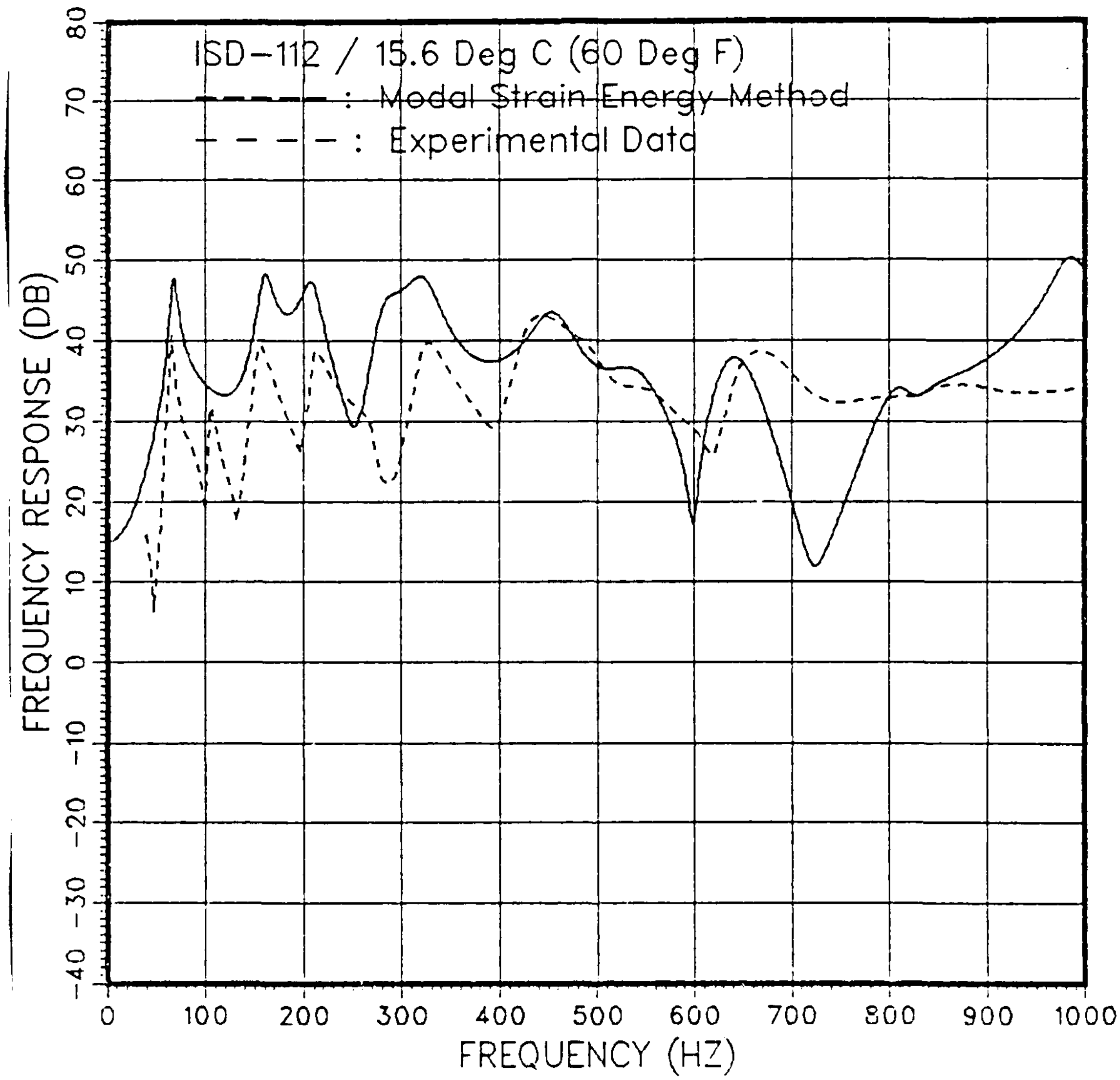

Figure 4.30. Comparison of Estimated and Measured Frequency Response for the Spot Welded Floating Element Configuration.

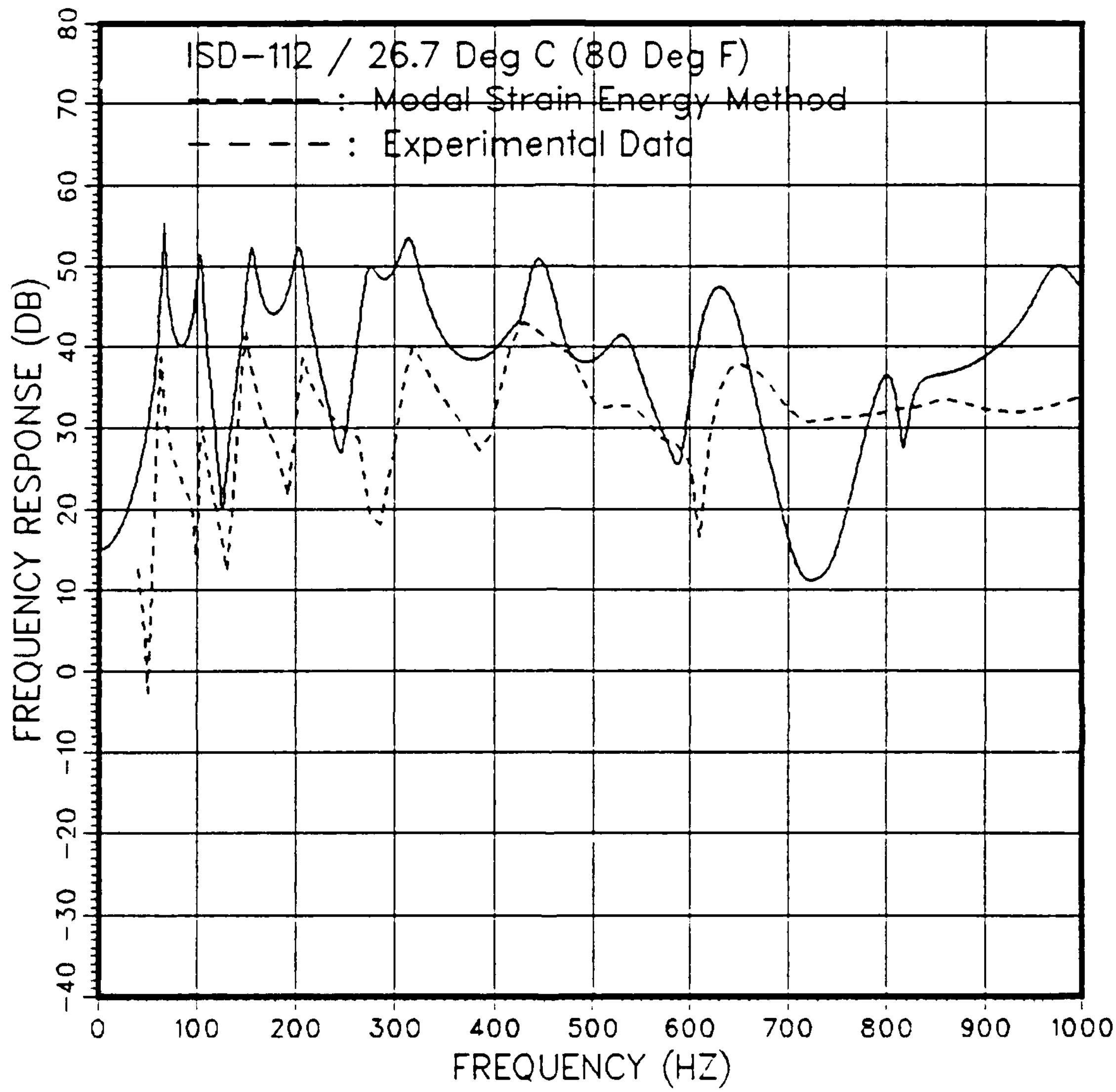

Figure 4.31. Comparison of Estimated and Measured Frequency Response for the Spot Welded Floating Element Configuration.

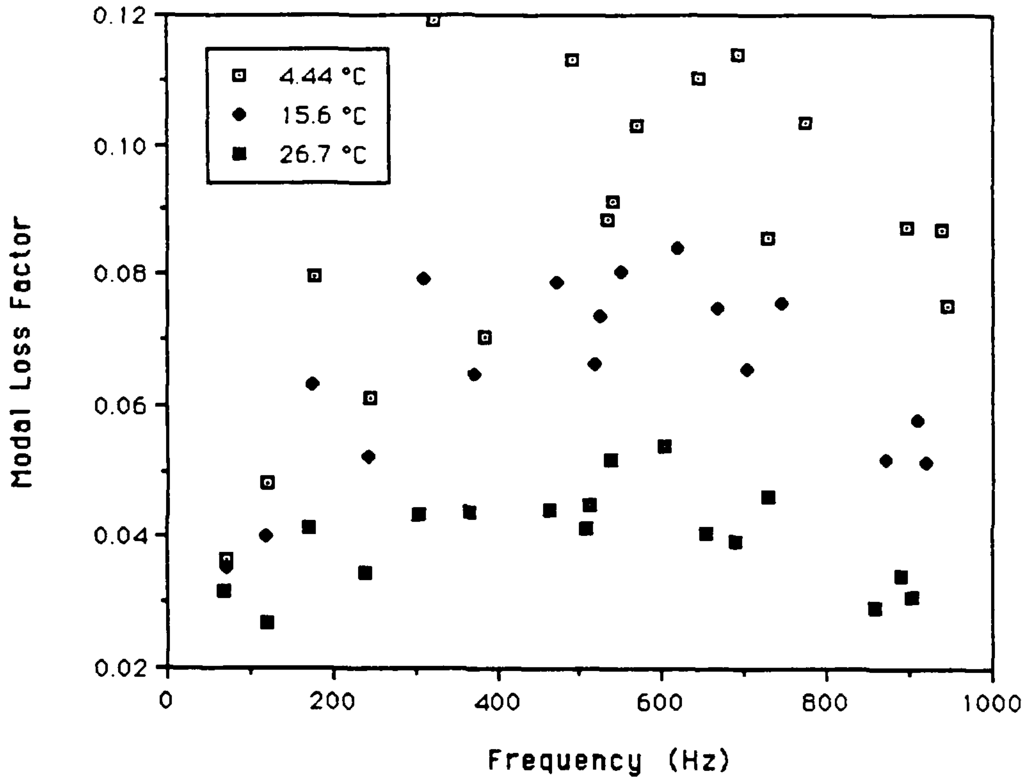

Figure 4.32. Modal Loss Factor for Line Welded Floating Element at 4.44/15.6/26.7 °C.

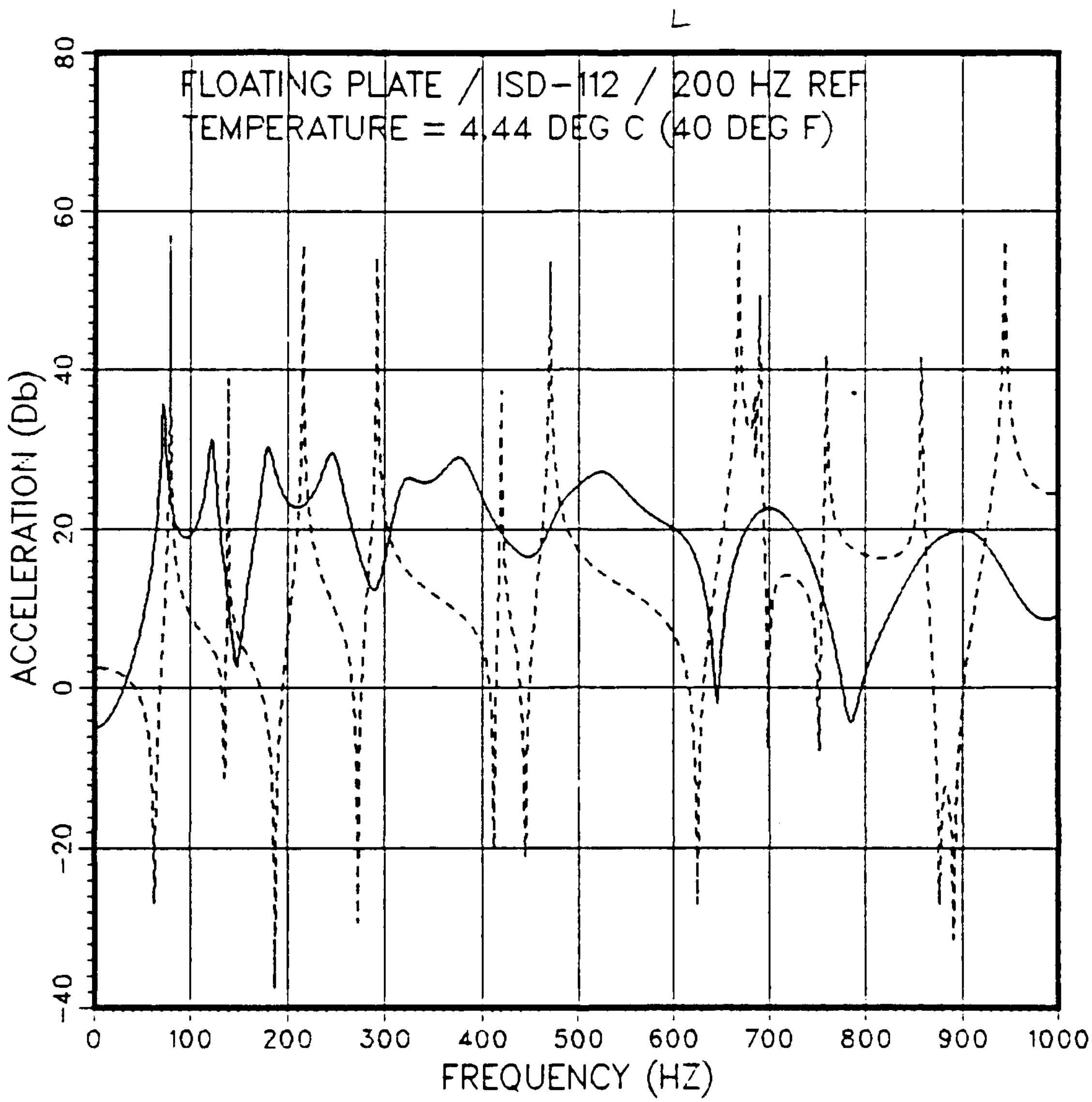

Figure 4.33. Calculated Modal Frequency Response of the Line Welded Floating Element Configuration Using NASTRAN.

[- - - - : reference plate , ——— : line welded pocket plate]

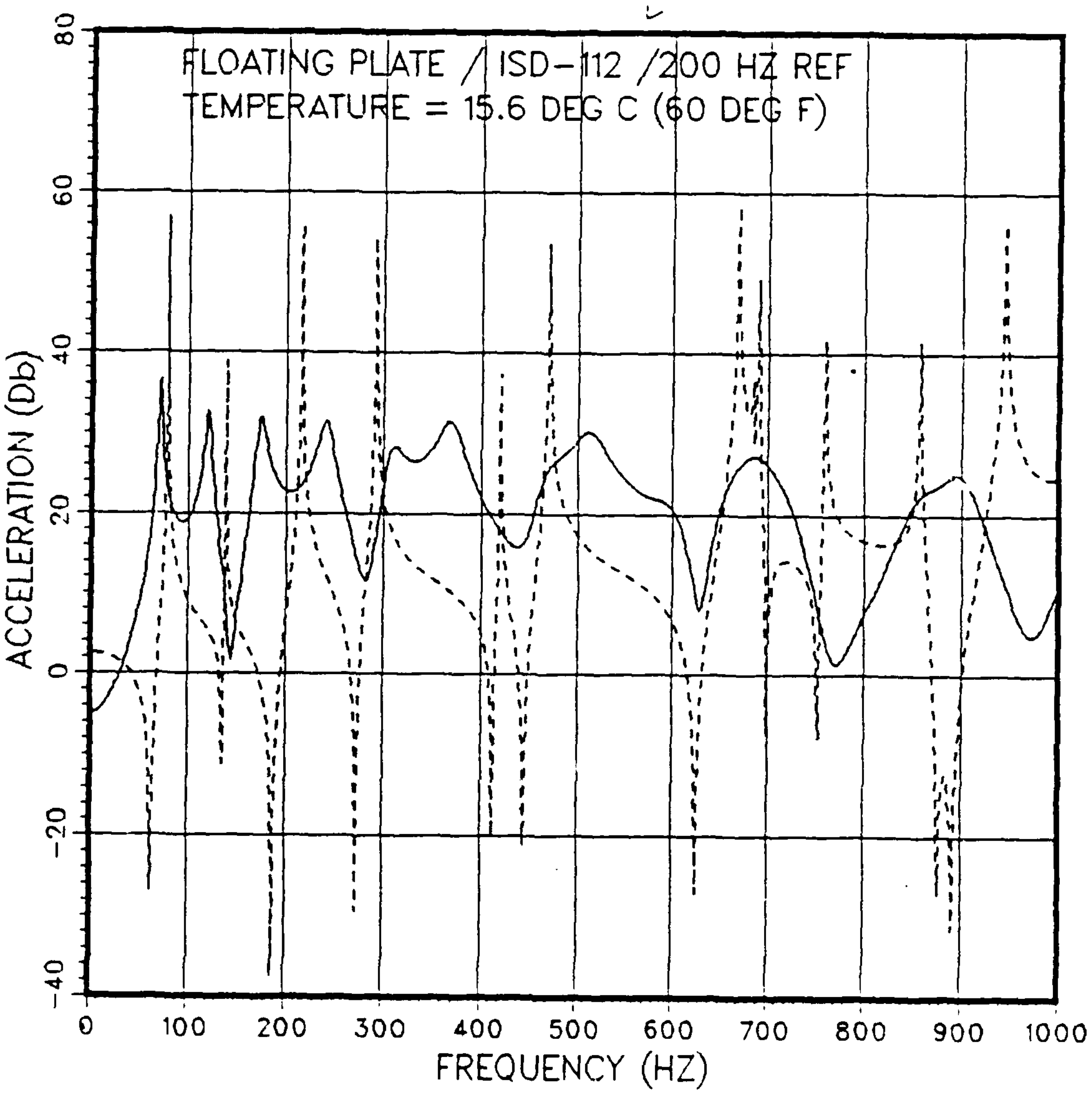

Figure 4.34. Calculated Modal Frequency Response of the Line Welded Floating Element Configuration Using NASTRAN.

[- - - - : reference plate , ——— : line welded pocket plate]

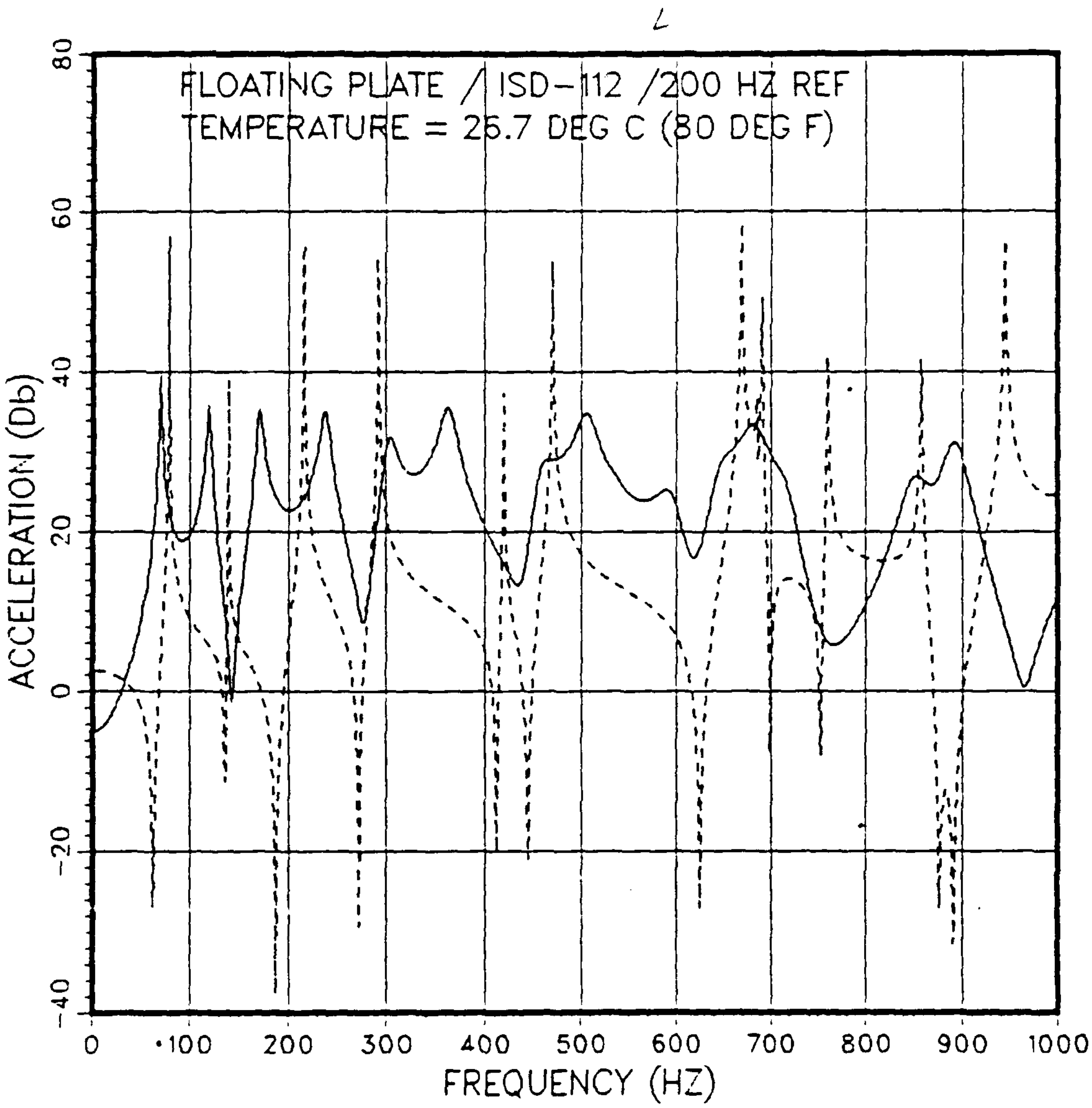

Figure 4.35. Calculated Modal Frequency Response of the Line Welded Floating Element Configuration Using NASTRAN.

[- - - - : reference plate , ——— : line welded pocket plate]

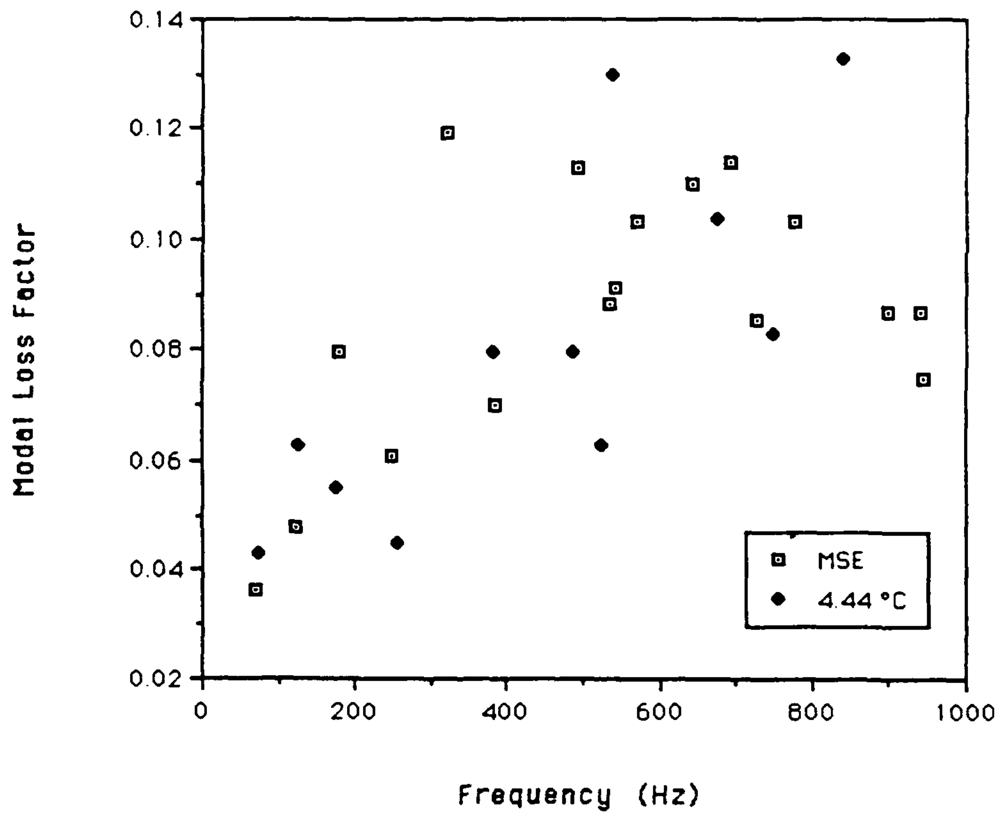

Figure 4.36. Comparison of Estimated and Measured Modal Loss Factors for Line Welded Floating Element Configuration.

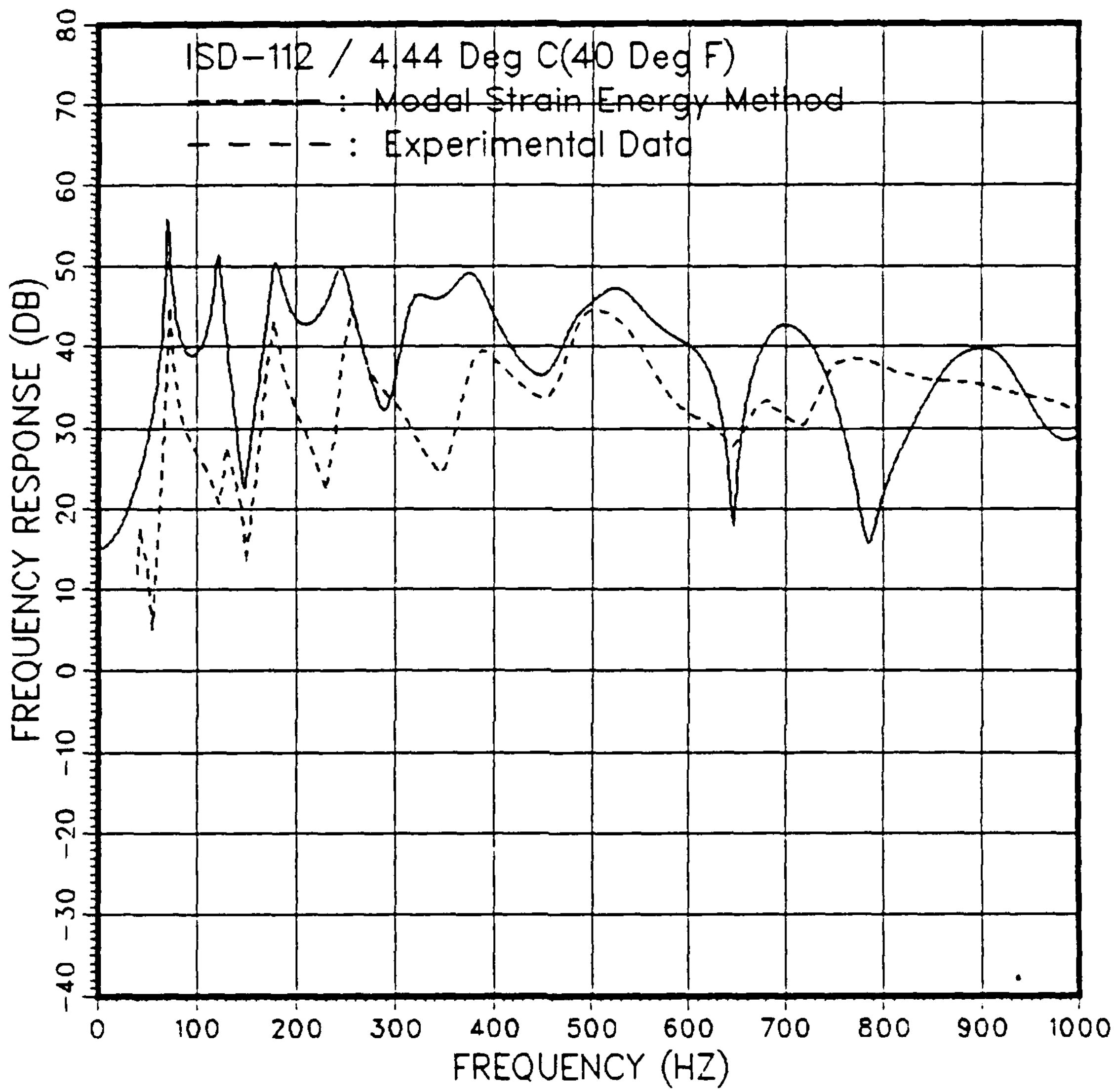

Figure 4.37. Comparison of Estimated and Measured Frequency Response for the Line Welded Floating Element Configuration.

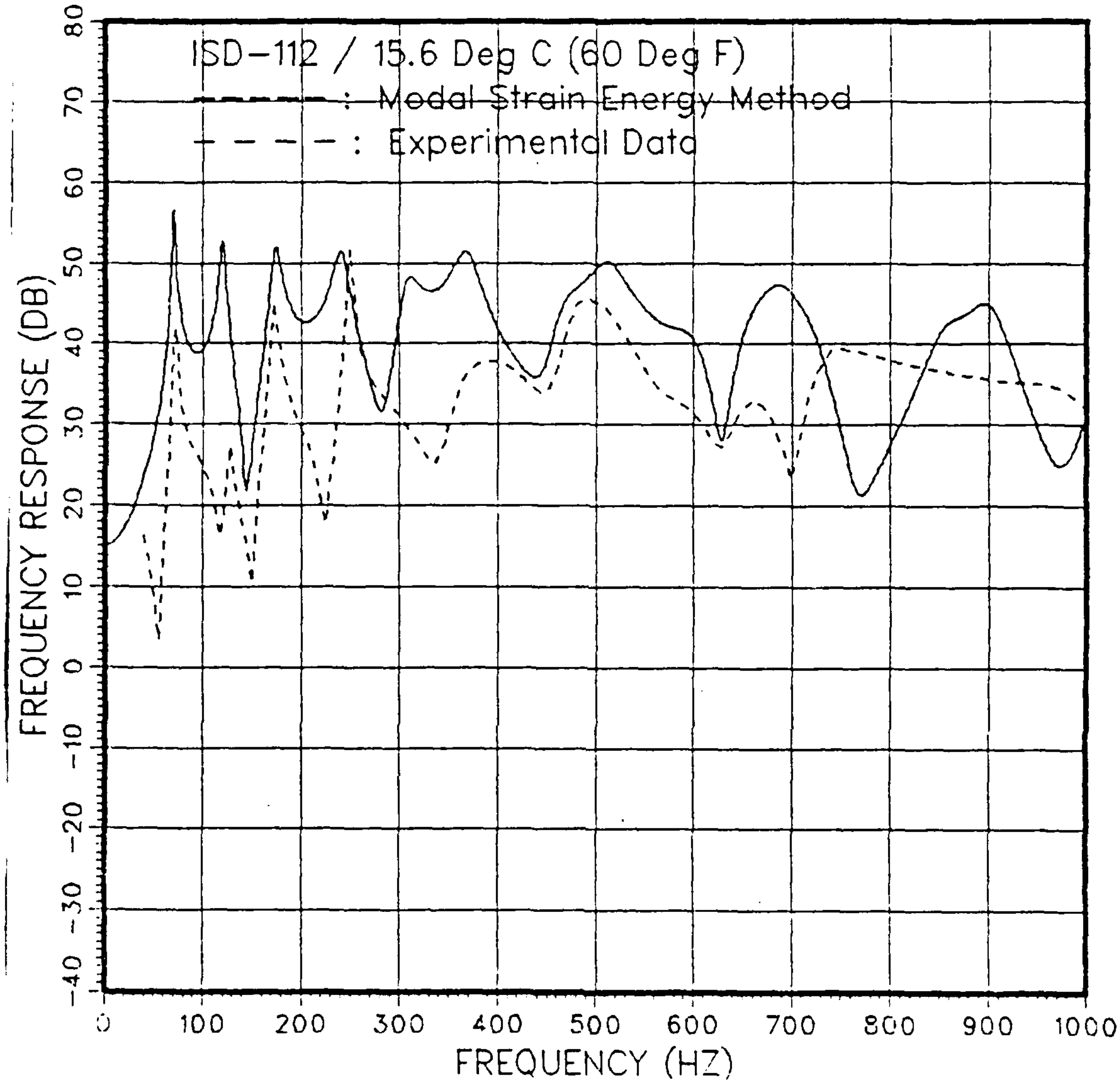

Figure 4.38. Comparison of Estimated and Measured Frequency Response for the Line Welded Floating Element Configuration.

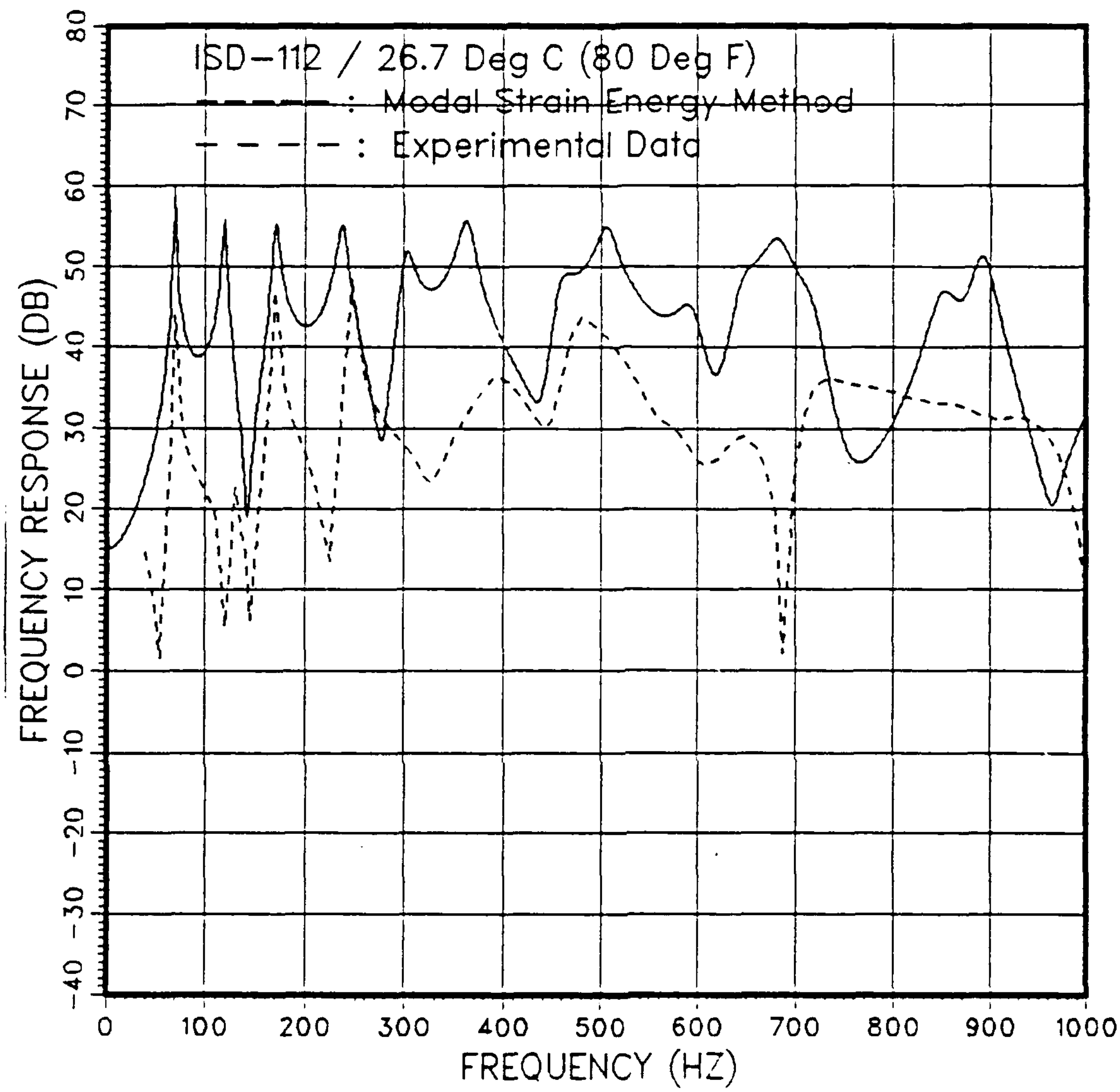

Figure 4.39. Comparison of Estimated and Measured Frequency Response for the Line Welded Floating Element Configuration.

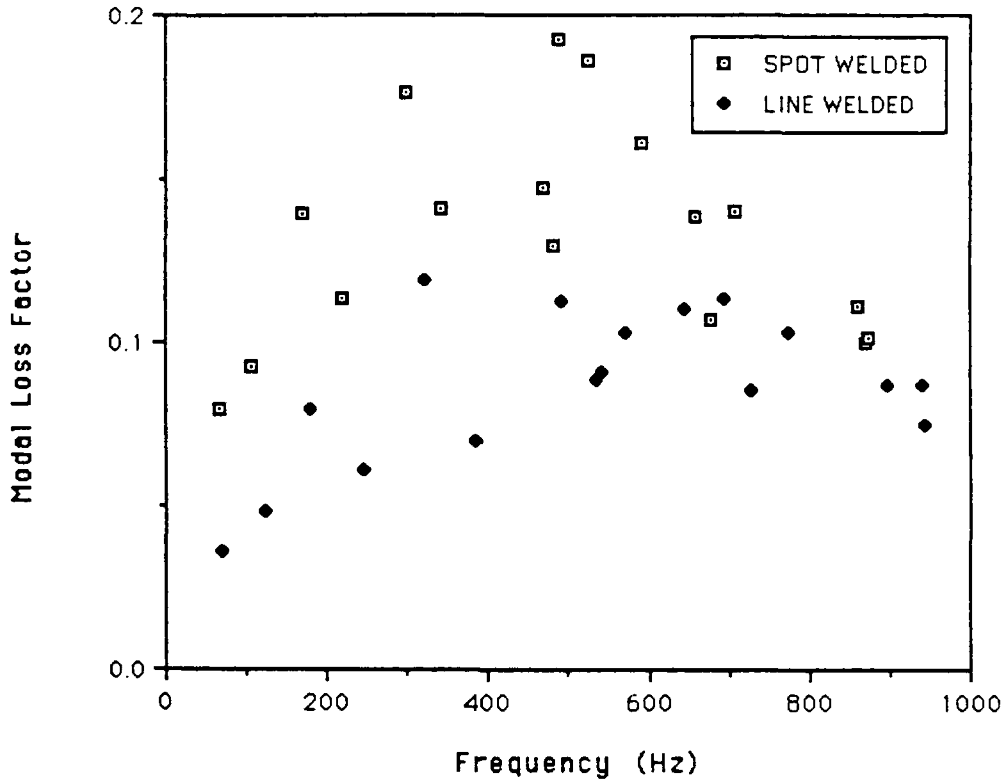

Figure 4.40. Comparison of Modal Loss Factor for Spot and Line Welded Floating Element at 4.44 °C.

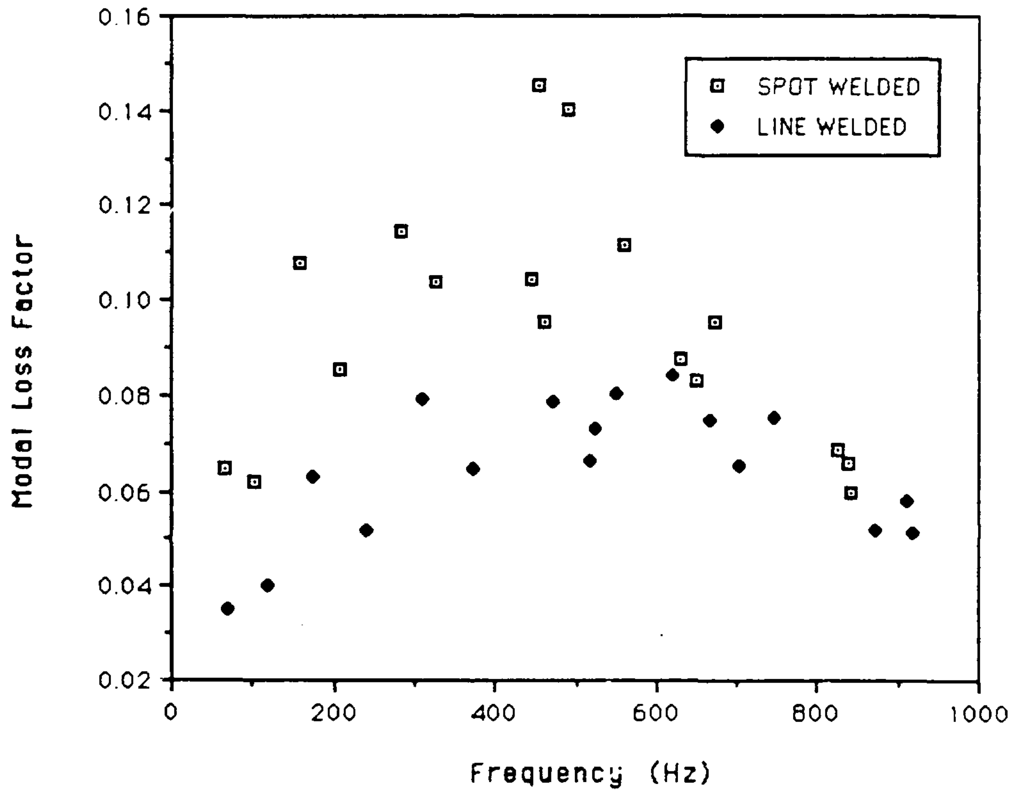

Figure 4.41. Comparison of Modal Loss Factor for Spot and Line Welded Floating Element at 15.6 °C.

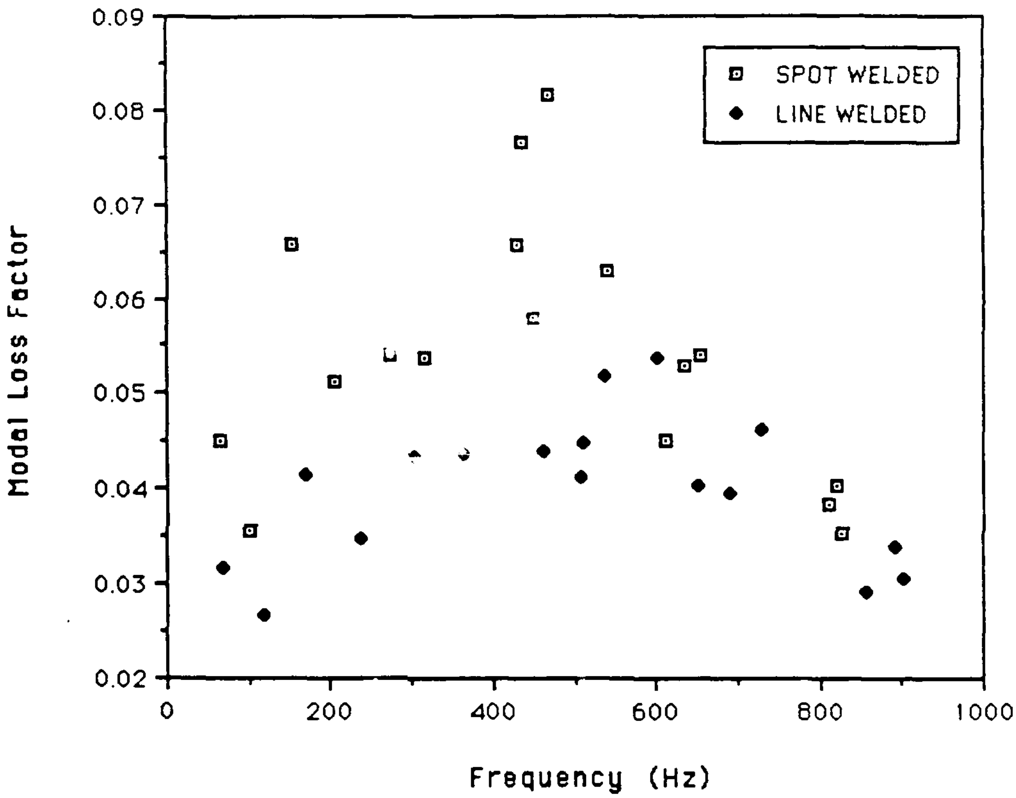

Figure 4.42. Comparison of Modal Loss Factor for Spot and Line Welded Floating Element at 26.7 °C.

V. CONCLUSIONS

In this paper I investigated the effectiveness of the Modal Strain Energy Method fo the estimation of the modal loss factor of milled pocket plate and floating element plate which are two new configurations of the constrained viscoelastic layer damping treaments. Both of the experimental and estimated data show a very similar results as can be seen in Figure 5.1 and 5.2. It also shows that the new constrained viscoelastic layer damping treatments are extremely effective ways for the reduction of the vibration from structures.

Comparison with the previous works by Bateman [Ref. 2], shows that the double layer modal have the highest damping result. However, for welded configurations, the floating element concept is more effective to reduce the vibration than the pocket plate concept. The modal loss factor of the floating element plate in average is 25 percent over the pocket plate.

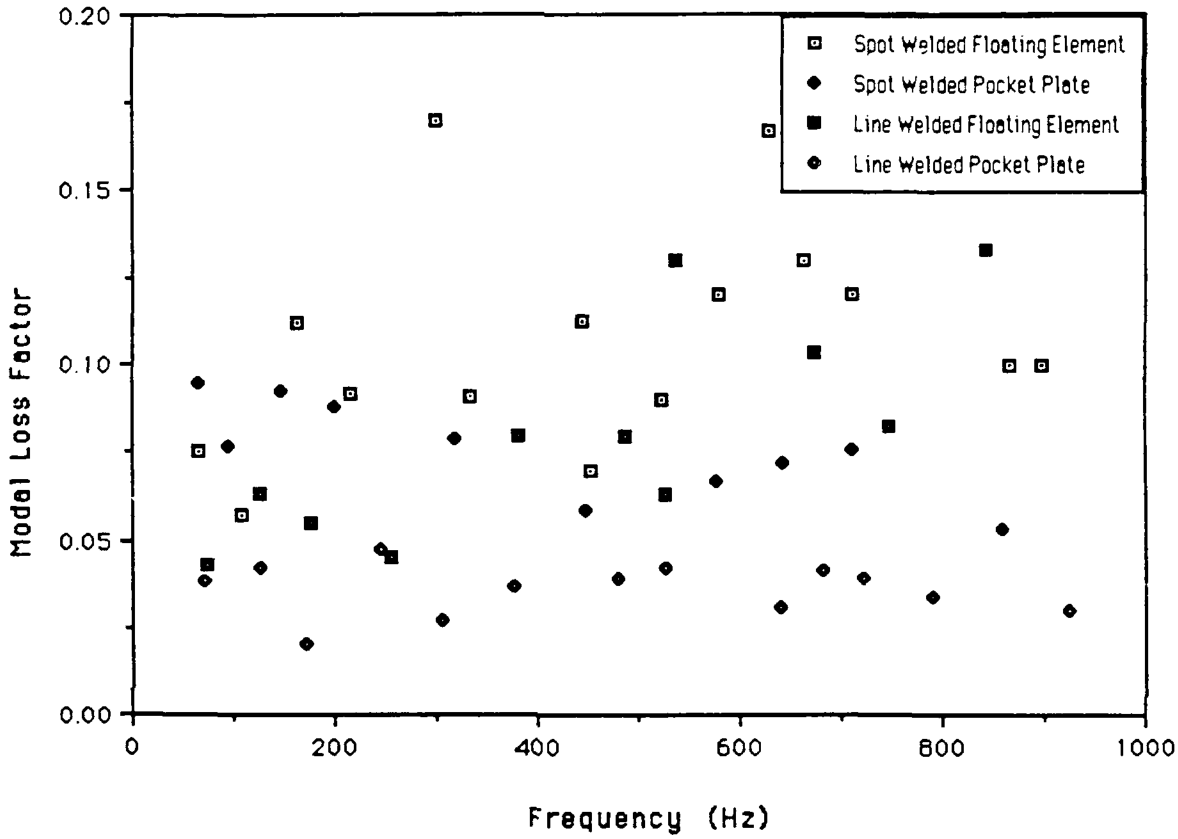

Figure 5.1. Comparisun of Experimentally Measured Modal Loss Factor for the Four Damping Configuration

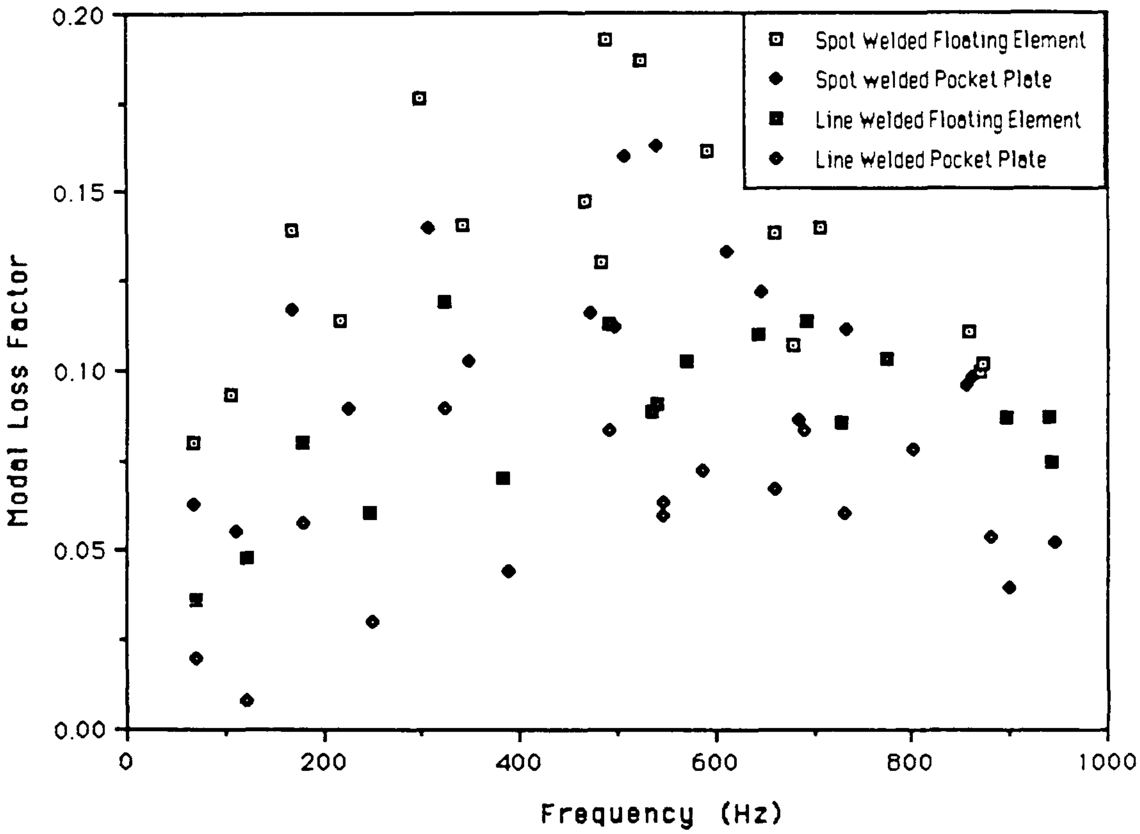

Figure 5.2. Comparison of Estimated Modal Loss Factors for the Spot and Line Welded Pocket Plate and Floating Element.

APPENDIX A. DESIGN DRAWINGS FOR THE MACHINING OF THE FLOATING ELEMENT AND POCKET PLATE CONFIGURATIONS

The drawings shown in Figures A.1 and A.2 [Ref. 2] were used to machine the pocket plate and floating element plate used in the experiments. These drawings are included to show the relation of the pocket for the ISD-112 to the cover plate and how the viscoelastic was protected from the heat of welding.

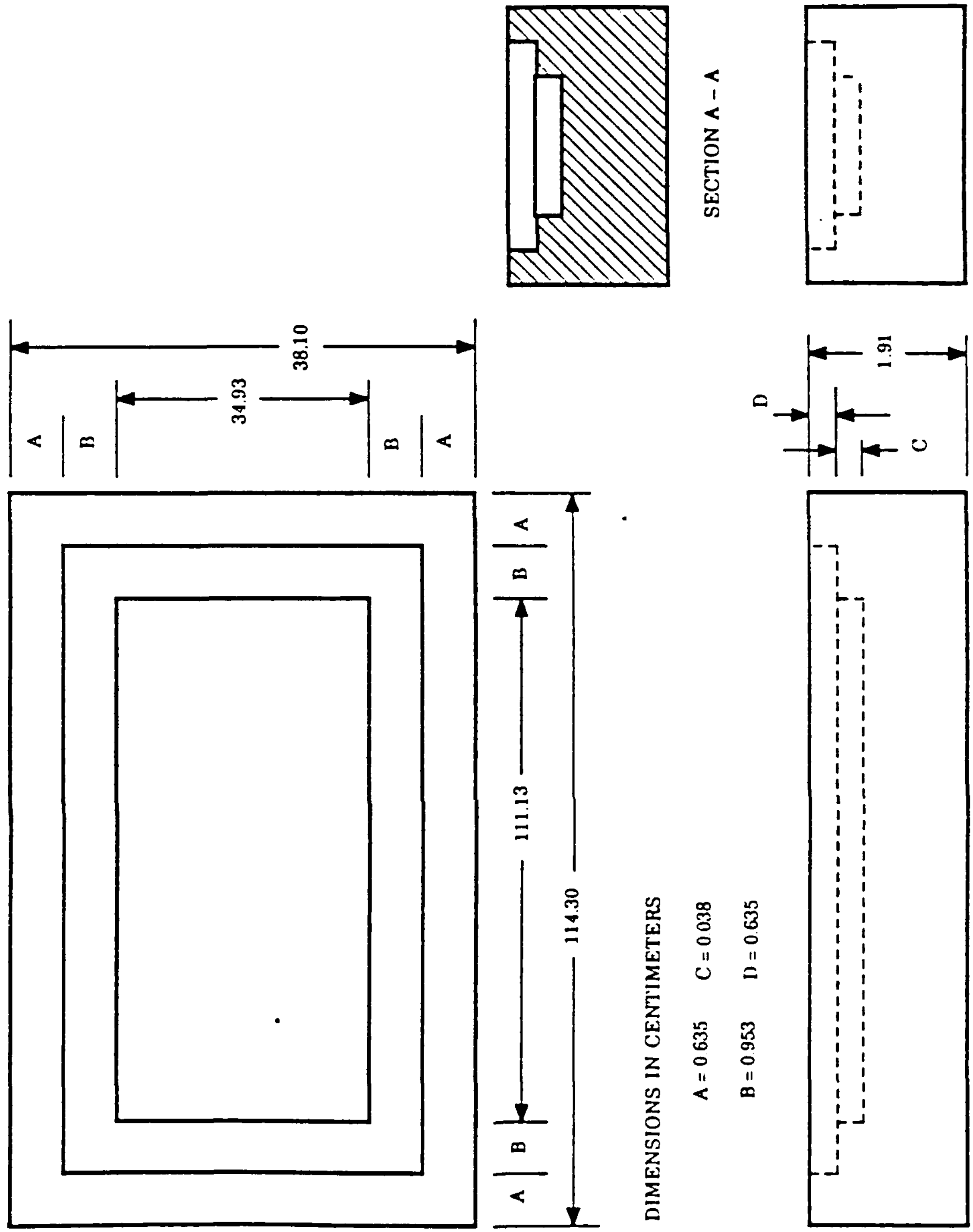

Figure A.1. Design Drawing of the Pocket Plate Configuration.

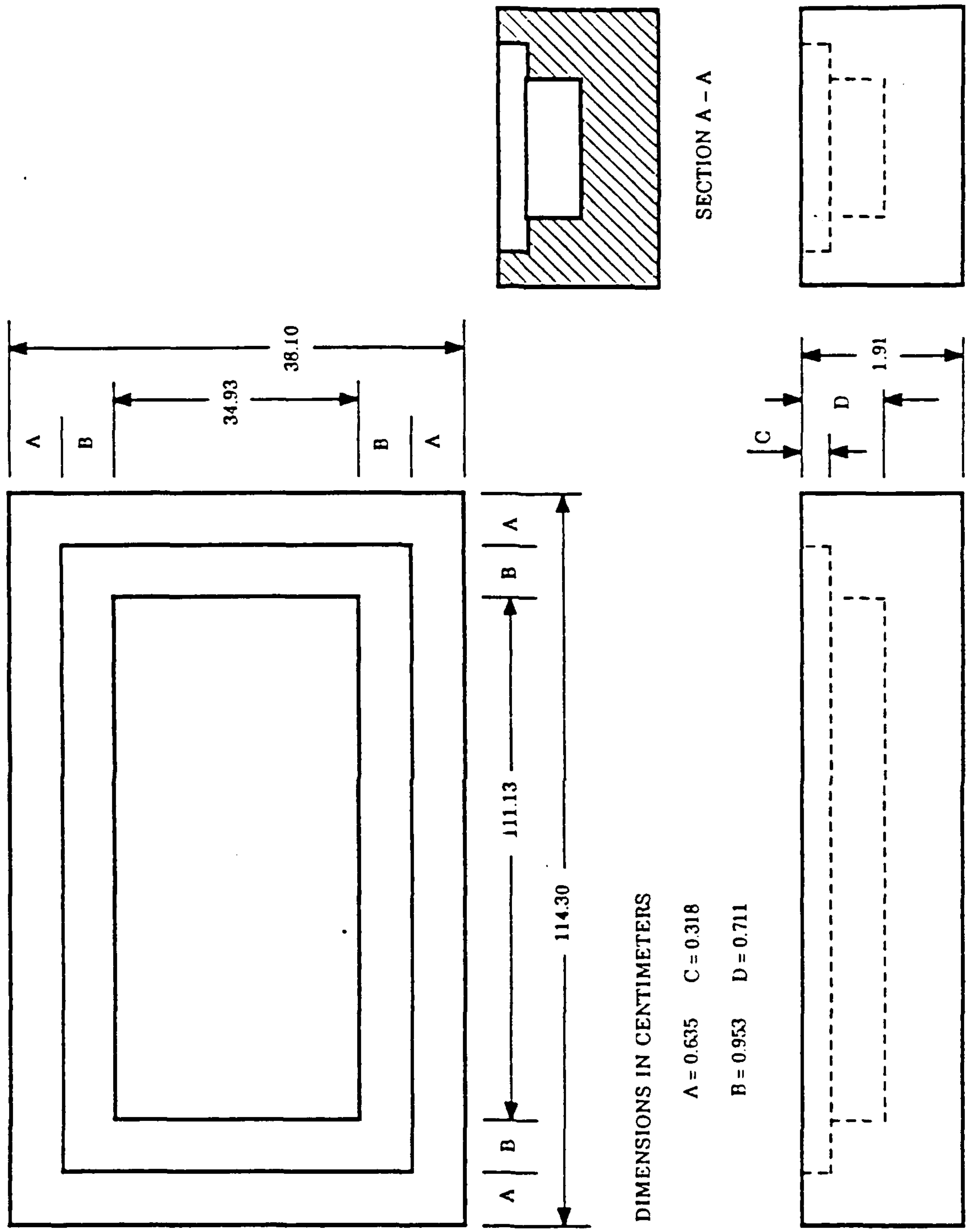

Figure A.2. Design Drawing of the Floating Element Configuration.

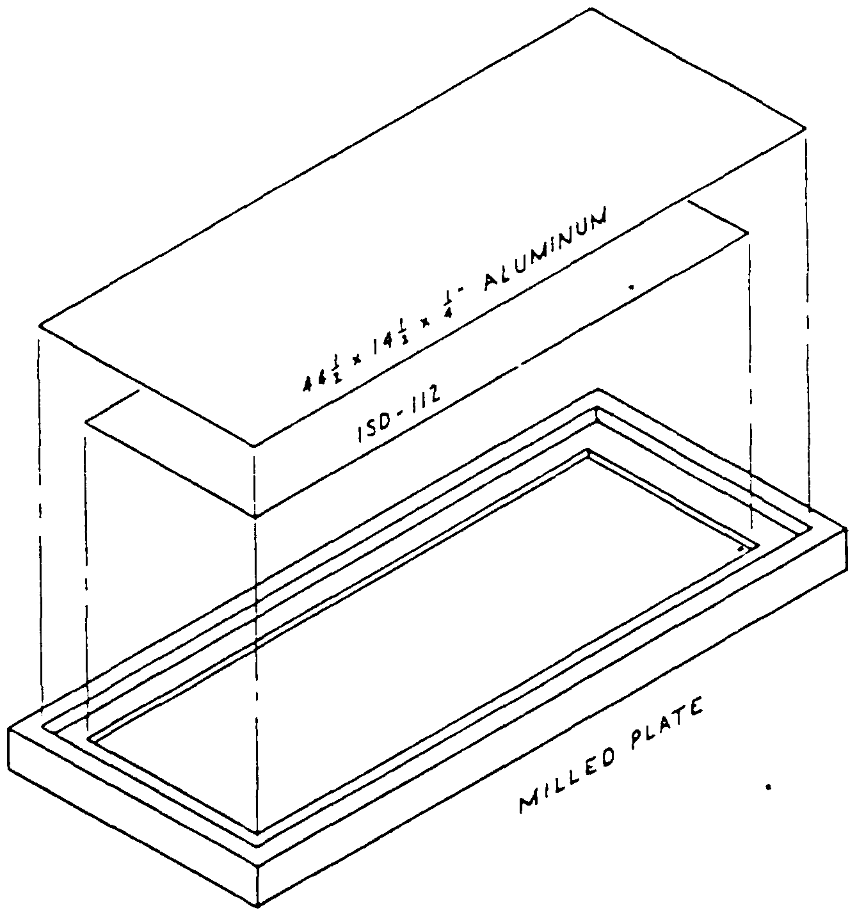

Figure A.3. General Arrangement of the Pocket Plate Configuration.

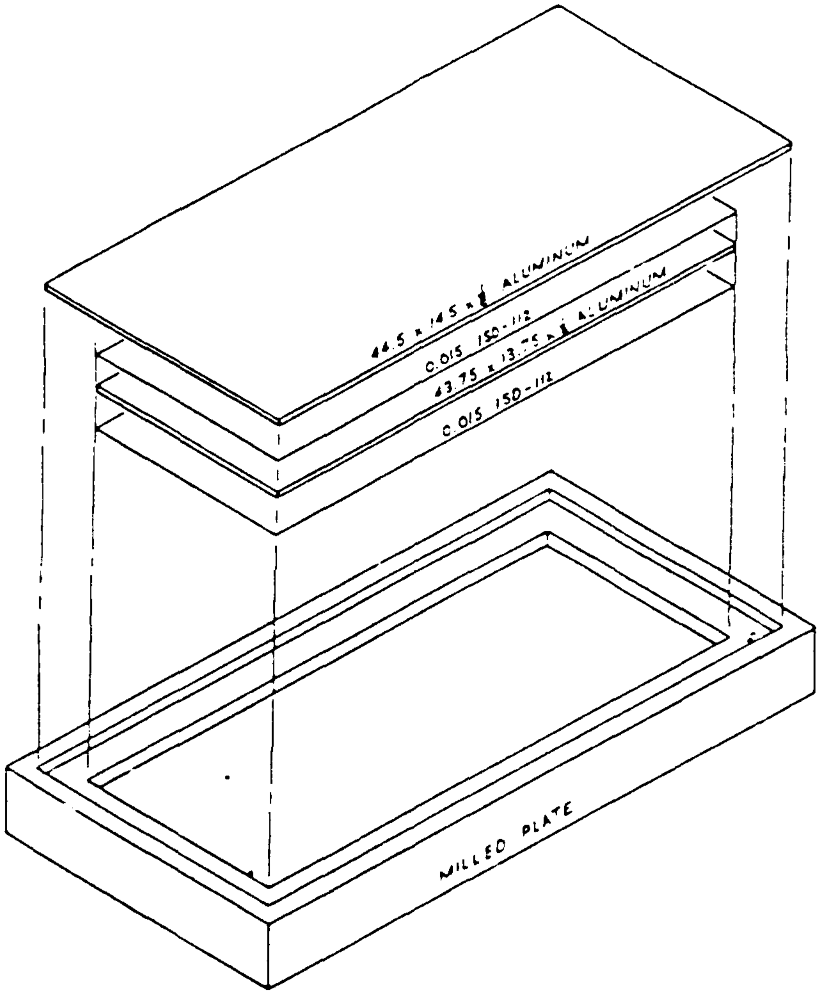

Figure A.4. Floating Element System Configuration.

APPENDIX B. SCALING AND GAIN FACTORS OF EXPERIMENTAL RESULTS FOR CORRECTING TO NASTRAN LEVEL

Experimental results are corrected to NASTRAN levels using the scaling factors and gains for the vibration generator, accelerometer, and charge amplifier used in the lab. These data are shown as follow:

Snsitivity of vibration generator	=	1060.0	pc/lb
Sensitivity of charge amplifier	=	1.060	pc/unit
Charge amplifier gain	=	10000.0	unit/volt
Accelerometer sensitivity	=	0.010	volt/G
Acceleration of grativy	=	386.0	in/sec/sec

APPENDIX C. REPRESENTATIVE MSC/NASTRAN DATA DECK FOR THE DAMPING CALCULATIONS

This data deck was used to compute the modal frequency response of the spot welded floating element plate configuration and is a representative sample of the MSC/NASTRAN decks used for the other finite element models. The values in the damping table are from a curve fit to the modal loss factors estimated from the modal strain energy method. Since the data deck for the normal mode and modal strain energy extraction is virtually identical to this deck, the Case Control deck commands for the normal mode analysis are included, but are commented out.

The OUTPUT request provides data for an x-y plot of the frequency response.

The units used in this deck are pounds, inches, and seconds.

```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$       THIS DECK IS TO COMPUTE THE MODAL FREQUENCY RESPONSE OF A 15x45
$ INCH ALUMINUM PLATE WITH A CONSTRAINED VISCOELASTIC DAMPING LAYER.
$ THE MODEL HAS 252 ELEMENTS WITH 84 ELEMENTS IN EACH LAYER.  THE QUAD
$ ELEMENTS ARE OFFSET FROM THE HEXA ELEMENTS AS SUGGESTED BY THE
$ LITERATURE.
$
$       THE MATERIAL PROPERTIES OF ISD-112 ARE FROM THE 3M CORPORATION.
$
$       THE MODAL LOSS FACTORS IN THE DAMPING TABLE ARE FROM A CURVE-FIT
$ TO THE SET OF MODAL LOSS FACTORS COMPUTED FROM THE MODAL STRAIN ENERGY
$ METHOD.
$
$       THIS DECK IS FOR LINE WELDED FLOATING ELEMENT AT 4.44 DEG C
$ (40 DEG F). THE UNITS USED IN THIS DECK ARE POUNDS, INCHES, AND SECONDS.
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
id float40,mfr
sol 30
time 6000
cend
title =200 HZ/FREQUENCY RESPONSE /LINE WELDED FLT / 40 ELEMENTS/ 40F
method = 1
spc = 1
dload = 10
frequency = 10
sdamping = 101
set 111 =95
svector =all
acceleration(plot,phase) = 111
output(xyplot)
xyprint acce / 95(t3)
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$       THE FOLLOWING LINES ARE THE CASE CONTROL DEACK CARDS FOR THE
$ NORMAL MODE EXTRACTION AND STRAIN ENERGY REQUEST
$ method = 1
$ spc = 1
$ set 10 = all
$ set 11 = 145,thru,504
$ ses = 11
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
BEGIN BULK
GRID           1          0.00000 0.00000 0.47000
GRID           2          0.00000 0.62500 0.47000
GRID           3          0.00000 4.06250 0.47000
GRID           4          0.00000 7.50000 0.47000
GRID           5          0.00000 10.9375 0.47000
GRID           6          0.00000 14.3750 0.47000
GRID           7          0.00000 15.0000 0.47000
GRID           8          0.62500 0.00000 0.47000
GRID           9          0.62500 0.62500 0.47000
GRID          10          0.62500 4.06250 0.47000
GRID          11          0.62500 7.50000 0.47000
GRID          12          0.62500 10.9375 0.47000
GRID          13          0.62500 14.3750 0.47000
GRID          14          0.62500 15.0000 0.47000
GRID          15          5.00000 0.00000 0.47000
```

GRID	16	5.00000	0.62500	0.47000
GRID	17	5.00000	4.06250	0.47000
GRID	18	5.00000	7.50000	0.47000
GRID	19	5.00000	10.9375	0.47000
GRID	20	5.00000	14.3750	0.47000
GRID	21	5.00000	15.0000	0.47000
GRID	22	9.37500	0.00000	0.47000
GRID	23	9.37500	0.62500	0.47000
GRID	24	9.37500	4.06250	0.47000
GRID	25	9.37500	7.50000	0.47000
GRID	26	9.37500	10.9375	0.47000
GRID	27	9.37500	14.3750	0.47000
GRID	28	9.37500	15.0000	0.47000
GRID	29	13.7500	0.00000	0.47000
GRID	30	13.7500	0.62500	0.47000
GRID	31	13.7500	4.06250	0.47000
GRID	32	13.7500	7.50000	0.47000
GRID	33	13.7500	10.9375	0.47000
GRID	34	13.7500	14.3750	0.47000
GRID	35	13.7500	15.0000	0.47000
GRID	36	18.1250	0.00000	0.47000
GRID	37	18.1250	0.62500	0.47000
GRID	38	18.1250	4.06250	0.47000
GRID	39	18.1250	7.50000	0.47000
GRID	40	18.1250	10.9375	0.47000
GRID	41	18.1250	14.3750	0.47000
GRID	42	18.1250	15.0000	0.47000
GRID	43	22.5000	0.00000	0.47000
GRID	44	22.5000	0.62500	0.47000
GRID	45	22.5000	4.06250	0.47000
GRID	46	22.5000	7.50000	0.47000
GRID	47	22.5000	10.9375	0.47000
GRID	48	22.5000	14.3750	0.47000
GRID	49	22.5000	15.0000	0.47000
GRID	50	26.8750	0.00000	0.47000
GRID	51	26.8750	0.62500	0.47000
GRID	52	26.8750	4.06250	0.47000
GRID	53	26.8750	7.50000	0.47000
GRID	54	26.8750	10.9375	0.47000
GRID	55	26.8750	14.3750	0.47000
GRID	56	26.8750	15.0000	0.47000
GRID	57	31.2500	0.00000	0.47000
GRID	58	31.2500	0.62500	0.47000
GRID	59	31.2500	4.06250	0.47000
GRID	60	31.2500	7.50000	0.47000
GRID	61	31.2500	10.9375	0.47000
GRID	62	31.2500	14.3750	0.47000
GRID	63	31.2500	15.0000	0.47000
GRID	64	35.6250	0.00000	0.47000
GRID	65	35.6250	0.62500	0.47000
GRID	66	35.6250	4.06250	0.47000
GRID	67	35.6250	7.50000	0.47000
GRID	68	35.6250	10.9375	0.47000
GRID	69	35.6250	14.3750	0.47000
GRID	70	35.6250	15.0000	0.47000
GRID	71	40.0000	0.00000	0.47000
GRID	72	40.0000	0.62500	0.47000
GRID	73	40.0000	4.06250	0.47000
GRID	74	40.0000	7.50000	0.47000
GRID	75	40.0000	10.9375	0.47000

GRID	76	40.0000	14.3750	0.47000	
GRID	77	40.0000	15.0000	0.47000	
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GRID	80	44.3750	4.06250	0.47000	
GRID	81	44.3750	7.50000	0.47000	
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GRID	83	44.3750	14.3750	0.47000	
GRID	84	44.3750	15.0000	0.47000	
GRID	85	45.0000	0.00000	0.47000	
GRID	86	45.0000	0.62500	0.47000	
GRID	87	45.0000	4.06250	0.47000	
GRID	88	45.0000	7.50000	0.47000	
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GRID	90	45.0000	14.3750	0.47000	
GRID	91	45.0000	15.0000	0.47000	
GRID	92	0.00000	0.00000	0.48500	
GRID	93	0.00000	0.62500	0.48500	
GRID	94	0.00000	0.63000	0.48500	123456
GRID	95	0.00000	4.06250	0.48500	
GRID	96	0.00000	7.50000	0.48500	
GRID	97	0.00000	10.9375	0.48500	
GRID	98	0.00000	14.3700	0.48500	123456
GRID	99	0.00000	14.3750	0.48500	
GRID	100	0.00000	15.0000	0.48500	
GRID	101	0.62500	0.00000	0.48500	
GRID	102	0.62500	0.62500	0.48500	
GRID	103	0.62500	0.63000	0.48500	123456
GRID	104	0.62500	4.06250	0.48500	
GRID	105	0.62500	7.50000	0.48500	
GRID	106	0.62500	10.9375	0.48500	
GRID	107	0.62500	14.3700	0.48500	123456
GRID	108	0.62500	14.3750	0.48500	
GRID	109	0.62500	15.0000	0.48500	
GRID	110	0.63000	0.00000	0.48500	123456
GRID	111	0.63000	0.62500	0.48500	123456
GRID	112	0.63000	0.63000	0.48500	
GRID	113	0.63000	4.06250	0.48500	
GRID	114	0.63000	7.50000	0.48500	
GRID	115	0.63000	10.9375	0.48500	
GRID	116	0.63000	14.3700	0.48500	
GRID	117	0.63000	14.3750	0.48500	123456
GRID	118	0.63000	15.0000	0.48500	123456
GRID	119	5.00000	0.00000	0.48500	
GRID	120	5.00000	0.62500	0.48500	
GRID	121	5.00000	0.63000	0.48500	
GRID	122	5.00000	4.06250	0.48500	
GRID	123	5.00000	7.50000	0.48500	
GRID	124	5.00000	10.9375	0.48500	
GRID	125	5.00000	14.3700	0.48500	
GRID	126	5.00000	14.3750	0.48500	
GRID	127	5.00000	15.0000	0.48500	
GRID	128	9.37500	0.00000	0.48500	
GRID	129	9.37500	0.62500	0.48500	
GRID	130	9.37500	0.63000	0.48500	
GRID	131	9.37500	4.06250	0.48500	
GRID	132	9.37500	7.50000	0.48500	
GRID	133	9.37500	10.9375	0.48500	
GRID	134	9.37500	14.3700	0.48500	
GRID	135	9.37500	14.3750	0.48500	

GRID	136	9.37500	15.0000	0.48500
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GRID	139	13.7500	0.63000	0.48500
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GRID	141	13.7500	7.50000	0.48500
GRID	142	13.7500	10.9375	0.48500
GRID	143	13.7500	14.3700	0.48500
GRID	144	13.7500	14.3750	0.48500
GRID	145	13.7500	15.0000	0.48500
GRID	146	18.1250	0.00000	0.48500
GRID	147	18.1250	0.62500	0.48500
GRID	148	18.1250	0.63000	0.48500
GRID	149	18.1250	4.06250	0.48500
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GRID	151	18.1250	10.9375	0.48500
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GRID	153	18.1250	14.3750	0.48500
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GRID	155	22.5000	0.00000	0.48500
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GRID	161	22.5000	14.3700	0.48500
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GRID	163	22.5000	15.0000	0.48500
GRID	164	26.8750	0.00000	0.48500
GRID	165	26.8750	0.62500	0.48500
GRID	166	26.8750	0.63000	0.48500
GRID	167	26.8750	4.06250	0.48500
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GRID	195	40.0000	7.50000	0.48500

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GRID	201	44.3700	0.62500	0.48500	123456
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GRID	204	44.3700	7.50000	0.48500	
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GRID	207	44.3700	14.3750	0.48500	123456
GRID	208	44.3700	15.0000	0.48500	123456
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GRID	210	44.3750	0.62500	0.48500	
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GRID	212	44.3750	4.06250	0.48500	
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GRID	216	44.3750	14.3750	0.48500	
GRID	217	44.3750	15.0000	0.48500	
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GRID	219	45.0000	0.62500	0.48500	
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GRID	221	45.0000	4.06250	0.48500	
GRID	222	45.0000	7.50000	0.48500	
GRID	223	45.0000	10.9375	0.48500	
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GRID	225	45.0000	14.3750	0.48500	
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GRID	228	0.00000	0.62500	0.52667	
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GRID	231	0.00000	7.50000	0.52667	
GRID	232	0.00000	10.9375	0.52667	
GRID	233	0.00000	14.3700	0.52667	123456
GRID	234	0.00000	14.3750	0.52667	
GRID	235	0.00000	15.0000	0.52667	
GRID	236	0.62500	0.00000	0.52667	
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GRID	238	0.62500	0.63000	0.52667	123456
GRID	239	0.62500	4.06250	0.52667	
GRID	240	0.62500	7.50000	0.52667	
GRID	241	0.62500	10.9375	0.52667	
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GRID	243	0.62500	14.3750	0.52667	
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GRID	245	0.63000	0.00000	0.52667	123456
GRID	246	0.63000	0.62500	0.52667	123456
GRID	247	0.63000	0.63000	0.52667	
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GRID	250	0.63000	10.9375	0.52667	
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GRID	252	0.63000	14.3750	0.52667	123456
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GRID	255	5.00000	0.62500	0.52667	

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GRID	266	9.37500	4.06250	0.52667
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GRID	270	9.37500	14.3750	0.52667
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GRID	285	18.1250	7.50000	0.52667
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GRID	287	18.1250	14.3700	0.52667
GRID	288	18.1250	14.3750	0.52667
GRID	289	18.1250	15.0000	0.52667
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GRID	298	22.5000	15.0000	0.52667
GRID	299	26.8750	0.00000	0.52667
GRID	300	26.8750	0.62500	0.52667
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GRID	302	26.8750	4.06250	0.52667
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GRID	307	26.8750	15.0000	0.52667
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GRID	309	31.2500	0.62500	0.52667
GRID	310	31.2500	0.63000	0.52667
GRID	311	31.2500	4.06250	0.52667
GRID	312	31.2500	7.50000	0.52667
GRID	313	31.2500	10.9375	0.52667
GRID	314	31.2500	14.3700	0.52667
GRID	315	31.2500	14.3750	0.52667

GRID	316	31.2500	15.0000	0.52667	
GRID	317	35.6250	0.00000	0.52667	
GRID	318	35.6250	0.62500	0.52667	
GRID	319	35.6250	0.63000	0.52667	
GRID	320	35.6250	4.06250	0.52667	
GRID	321	35.6250	7.50000	0.52667	
GRID	322	35.6250	10.9375	0.52667	
GRID	323	35.6250	14.3700	0.52667	
GRID	324	35.6250	14.3750	0.52667	
GRID	325	35.6250	15.0000	0.52667	
GRID	326	40.0000	0.00000	0.52667	
GRID	327	40.0000	0.62500	0.52667	
GRID	328	40.0000	0.63000	0.52667	
GRID	329	40.0000	4.06250	0.52667	
GRID	330	40.0000	7.50000	0.52667	
GRID	331	40.0000	10.9375	0.52667	
GRID	332	40.0000	14.3700	0.52667	
GRID	333	40.0000	14.3750	0.52667	
GRID	334	40.0000	15.0000	0.52667	
GRID	335	44.3700	0.00000	0.52667	123456
GRID	336	44.3700	0.62500	0.52667	123456
GRID	337	44.3700	0.63000	0.52667	
GRID	338	44.3700	4.06250	0.52667	
GRID	339	44.3700	7.50000	0.52667	
GRID	340	44.3700	10.9375	0.52667	
GRID	341	44.3700	14.3700	0.52667	
GRID	342	44.3700	14.3750	0.52667	123456
GRID	343	44.3700	15.0000	0.52667	123456
GRID	344	44.3750	0.00000	0.52667	
GRID	345	44.3750	0.62500	0.52667	
GRID	346	44.3750	0.63000	0.52667	123456
GRID	347	44.3750	4.06250	0.52667	
GRID	348	44.3750	7.50000	0.52667	
GRID	349	44.3750	10.9375	0.52667	
GRID	350	44.3750	14.3700	0.52667	123456
GRID	351	44.3750	14.3750	0.52667	
GRID	352	44.3750	15.0000	0.52667	
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GRID	356	45.0000	4.06250	0.52667	
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GRID	369	0.00000	14.3750	0.56833	
GRID	370	0.00000	15.0000	0.56833	
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GRID	385	0.63000	10.9375	0.56833	
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GRID	408	13.7500	0.62500	0.56833	
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GRID	417	18.1250	0.62500	0.56833	
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GRID	457	35.6250	10.9375	0.56833	
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GRID	462	40.0000	0.62500	0.56833	
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GRID	471	44.3700	0.62500	0.56833	123456
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GRID	491	45.0000	4.06250	0.56833	
GRID	492	45.0000	7.50000	0.56833	
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GRID	504	0.00000	14.3750	0.61000	
GRID	505	0.00000	15.0000	0.61000	
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GRID	507	0.62500	0.62500	0.61000	
GRID	508	0.62500	0.63000	0.61000	123456
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GRID	516	0.63000	0.62500	0.61000	123456
GRID	517	0.63000	0.63000	0.61000	
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GRID	525	5.00000	0.62500	0.61000	
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GRID	534	9.37500	0.62500	0.61000	
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GRID	563	22.5000	4.06250	0.61000	
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GRID	594	35.6250	14.3750	0.61000	
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GRID	599	40.0000	4.06250	0.61000	
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GRID	603	40.0000	14.3750	0.61000	
GRID	604	40.0000	15.0000	0.61000	
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GRID	606	44.3700	0.62500	0.61000	123456
GRID	607	44.3700	0.63000	0.61000	
GRID	608	44.3700	4.06250	0.61000	
GRID	609	44.3700	7.50000	0.61000	
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GRID	611	44.3700	14.3700	0.61000	
GRID	612	44.3700	14.3750	0.61000	123456
GRID	613	44.3700	15.0000	0.61000	123456
GRID	614	44.3750	0.00000	0.61000	
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GRID	626	45.0000	4.06250	0.61000	
GRID	627	45.0000	7.50000	0.61000	
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GRID	636	0.00000	7.50000	0.62500	
GRID	637	0.00000	10.9375	0.62500	
GRID	638	0.00000	14.3700	0.62500	123456
GRID	639	0.00000	14.3750	0.62500	
GRID	640	0.00000	15.0000	0.62500	
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GRID	643	0.62500	0.63000	0.62500	123456
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GRID	648	0.62500	14.3750	0.62500	
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GRID	651	0.63000	0.62500	0.62500	123456
GRID	652	0.63000	0.63000	0.62500	123456
GRID	653	0.63000	4.06250	0.62500	123456
GRID	654	0.63000	7.50000	0.62500	123456
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GRID	656	0.63000	14.3700	0.62500	123456
GRID	657	0.63000	14.3750	0.62500	123456
GRID	658	0.63000	15.0000	0.62500	123456
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GRID	660	5.00000	0.62500	0.62500	
GRID	661	5.00000	0.63000	0.62500	123456
GRID	662	5.00000	4.06250	0.62500	
GRID	663	5.00000	7.50000	0.62500	
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GRID	670	9.37500	0.63000	0.62500	123456
GRID	671	9.37500	4.06250	0.62500	
GRID	672	9.37500	7.50000	0.62500	
GRID	673	9.37500	10.9375	0.62500	
GRID	674	9.37500	14.3700	0.62500	123456
GRID	675	9.37500	14.3750	0.62500	

GRID	676	9.37500	15.0000	0.62500	
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GRID	678	13.7500	0.62500	0.62500	
GRID	679	13.7500	0.63000	0.62500	123456
GRID	680	13.7500	4.06250	0.62500	
GRID	681	13.7500	7.50000	0.62500	
GRID	682	13.7500	10.9375	0.62500	
GRID	683	13.7500	14.3700	0.62500	123456
GRID	684	13.7500	14.3750	0.62500	
GRID	685	13.7500	15.0000	0.62500	
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GRID	687	18.1250	0.62500	0.62500	
GRID	688	18.1250	0.63000	0.62500	123456
GRID	689	18.1250	4.06250	0.62500	
GRID	690	18.1250	7.50000	0.62500	
GRID	691	18.1250	10.9375	0.62500	
GRID	692	18.1250	14.3700	0.62500	123456
GRID	693	18.1250	14.3750	0.62500	
GRID	694	18.1250	15.0000	0.62500	
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GRID	696	22.5000	0.62500	0.62500	
GRID	697	22.5000	0.63000	0.62500	123456
GRID	698	22.5000	4.06250	0.62500	
GRID	699	22.5000	7.50000	0.62500	
GRID	700	22.5000	10.9375	0.62500	
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GRID	702	22.5000	14.3750	0.62500	
GRID	703	22.5000	15.0000	0.62500	
GRID	704	26.8750	0.00000	0.62500	
GRID	705	26.8750	0.62500	0.62500	
GRID	706	26.8750	0.63000	0.62500	123456
GRID	707	26.8750	4.06250	0.62500	
GRID	708	26.8750	7.50000	0.62500	
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GRID	710	26.8750	14.3700	0.62500	123456
GRID	711	26.8750	14.3750	0.62500	
GRID	712	26.8750	15.0000	0.62500	
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GRID	714	31.2500	0.62500	0.62500	
GRID	715	31.2500	0.63000	0.62500	123456
GRID	716	31.2500	4.06250	0.62500	
GRID	717	31.2500	7.50000	0.62500	
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GRID	720	31.2500	14.3750	0.62500	
GRID	721	31.2500	15.0000	0.62500	
GRID	722	35.6250	0.00000	0.62500	
GRID	723	35.6250	0.62500	0.62500	
GRID	724	35.6250	0.63000	0.62500	123456
GRID	725	35.6250	4.06250	0.62500	
GRID	726	35.6250	7.50000	0.62500	
GRID	727	35.6250	10.9375	0.62500	
GRID	728	35.6250	14.3700	0.62500	123456
GRID	729	35.6250	14.3750	0.62500	
GRID	730	35.6250	15.0000	0.62500	
GRID	731	40.0000	0.00000	0.62500	
GRID	732	40.0000	0.62500	0.62500	
GRID	733	40.0000	0.63000	0.62500	123456
GRID	734	40.0000	4.06250	0.62500	
GRID	735	40.0000	7.50000	0.62500	

```
GRID         736             40.0000 10.9375 0.62500
GRID         737             40.0000 14.3700 0.62500         123456
GRID         738             40.0000 14.3750 0.62500
GRID         739             40.0000 15.0000 0.62500
GRID         740             44.3700 0.00000 0.62500         123456
GRID         741             44.3700 0.62500 0.62500         123456
GRID         742             44.3700 0.63000 0.62500         123456
GRID         743             44.3700 4.06250 0.62500         123456
GRID         744             44.3700 7.50000 0.62500         123456
GRID         745             44.3700 10.9375 0.62500         123456
GRID         746             44.3700 14.3700 0.62500         123456
GRID         747             44.3700 14.3750 0.62500         123456
GRID         748             44.3700 15.0000 0.62500         123456
GRID         749             44.3750 0.00000 0.62500
GRID         750             44.3750 0.62500 0.62500
GRID         751             44.3750 0.63000 0.62500         123456
GRID         752             44.3750 4.06250 0.62500
GRID         753             44.3750 7.50000 0.62500
GRID         754             44.3750 10.9375 0.62500
GRID         755             44.3750 14.3700 0.62500         123456
GRID         756             44.3750 14.3750 0.62500
GRID         757             44.3750 15.0000 0.62500
GRID         758             45.0000 0.00000 0.62500
GRID         759             45.0000 0.62500 0.62500
GRID         760             45.0000 0.63000 0.62500         123456
GRID         761             45.0000 4.06250 0.62500
GRID         762             45.0000 7.50000 0.62500
GRID         763             45.0000 10.9375 0.62500
GRID         764             45.0000 14.3700 0.62500         123456
GRID         765             45.0000 14.3750 0.62500
GRID         766             45.0000 15.0000 0.62500
CQUAD4         1       1       1       8       9       2               -.235
CQUAD4         2       1       2       9      10       3               -.235
CQUAD4         3       1       3      10      11       4               -.235
CQUAD4         4       1       4      11      12       5               -.235
CQUAD4         5       1       5      12      13       6               -.235
CQUAD4         6       1       6      13      14       7               -.235
CQUAD4         7       1      13      20      21      14               -.235
CQUAD4         8       1      20      27      28      21               -.235
CQUAD4         9       1      27      34      35      28               -.235
CQUAD4        10       1      34      41      42      35               -.235
CQUAD4        11       1      41      48      49      42               -.235
CQUAD4        12       1      48      55      56      49               -.235
CQUAD4        13       1      55      62      63      56               -.235
CQUAD4        14       1      62      69      70      63               -.235
CQUAD4        15       1      69      76      77      70               -.235
CQUAD4        16       1      76      83      84      77               -.235
CQUAD4        17       1      83      90      91      84               -.235
CQUAD4        18       1      82      89      90      83               -.235
CQUAD4        19       1      81      88      89      82               -.235
CQUAD4        20       1      80      87      88      81               -.235
CQUAD4        21       1      79      86      87      80               -.235
CQUAD4        22       1      78      85      86      79               -.235
CQUAD4        23       1      71      78      79      72               -.235
CQUAD4        24       1      64      71      72      65               -.235
CQUAD4        25       1      57      64      65      58               -.235
CQUAD4        26       1      50      57      58      51               -.235
CQUAD4        27       1      43      50      51      44               -.235
CQUAD4        28       1      36      43      44      37               -.235
CQUAD4        29       1      29      36      37      30               -.235
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CQUAD4	30	1	22	29	30	23	-.235
CQUAD4	31	1	15	22	23	16	-.235
CQUAD4	32	1	8	15	16	9	-.235
CQUAD4	33	1	9	16	17	10	-.235
CQUAD4	34	1	10	17	18	11	-.235
CQUAD4	35	1	11	18	19	12	-.235
CQUAD4	36	1	12	19	20	13	-.235
CQUAD4	37	1	16	23	24	17	-.235
CQUAD4	38	1	17	24	25	18	-.235
CQUAD4	39	1	18	25	26	19	-.235
CQUAD4	40	1	19	26	27	20	-.235
CQUAD4	41	1	23	30	31	24	-.235
CQUAD4	42	1	24	31	32	25	-.235
CQUAD4	43	1	25	32	33	26	-.235
CQUAD4	44	1	26	33	34	27	-.235
CQUAD4	45	1	30	37	38	31	-.235
CQUAD4	46	1	31	38	39	32	-.235
CQUAD4	47	1	32	39	40	33	-.235
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CQUAD4	49	1	37	44	45	38	-.235
CQUAD4	50	1	38	45	46	39	-.235
CQUAD4	51	1	39	46	47	40	-.235
CQUAD4	52	1	40	47	48	41	-.235
CQUAD4	53	1	44	51	52	45	-.235
CQUAD4	54	1	45	52	53	46	-.235
CQUAD4	55	1	46	53	54	47	-.235
CQUAD4	56	1	47	54	55	48	-.235
CQUAD4	57	1	51	58	59	52	-.235
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CQUAD4	60	1	54	61	62	55	-.235
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CQUAD4	62	1	59	66	67	60	-.235
CQUAD4	63	1	60	67	68	61	-.235
CQUAD4	64	1	61	68	69	62	-.235
CQUAD4	65	1	65	72	73	66	-.235
CQUAD4	66	1	66	73	74	67	-.235
CQUAD4	67	1	67	74	75	68	-.235
CQUAD4	68	1	68	75	76	69	-.235
CQUAD4	69	1	72	79	80	73	-.235
CQUAD4	70	1	73	80	81	74	-.235
CQUAD4	71	1	74	81	82	75	-.235
CQUAD4	72	1	75	82	83	76	-.235
CQUAD4	73	2	632	641	642	633	.0625
CQUAD4	74	2	633	642	644	635	.0625
CQUAD4	75	2	635	644	645	636	.0625
CQUAD4	76	2	636	645	646	637	.0625
CQUAD4	77	2	637	646	648	639	.0625
CQUAD4	78	2	639	648	649	640	.0625
CQUAD4	79	2	648	666	667	649	.0625
CQUAD4	80	2	666	675	676	667	.0625
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CQUAD4	82	2	684	693	694	685	.0625
CQUAD4	83	2	693	702	703	694	.0625
CQUAD4	84	2	702	711	712	703	.0625
CQUAD4	85	2	711	720	721	712	.0625
CQUAD4	86	2	720	729	730	721	.0625
CQUAD4	87	2	729	738	739	730	.0625
CQUAD4	88	2	738	756	757	739	.0625
CQUAD4	89	2	756	765	766	757	.0625

CQUAD4	90	2	754	763	765	756		.0625	
CQUAD4	91	2	753	762	763	754		.0625	
CQUAD4	92	2	752	761	762	753		.0625	
CQUAD4	93	2	750	759	761	752		.0625	
CQUAD4	94	2	749	758	759	750		.0625	
CQUAD4	95	2	731	749	750	732		.0625	
CQUAD4	96	2	722	731	732	723		.0625	
CQUAD4	97	2	713	722	723	714		.0625	
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CQUAD4	99	2	695	704	705	696		.0625	
CQUAD4	100	2	686	695	696	687		.0625	
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CQUAD4	102	2	668	677	678	669		.0625	
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CQUAD4	104	2	641	659	660	642		.0625	
CQUAD4	105	2	642	660	662	644		.0625	
CQUAD4	106	2	644	662	663	645		.0625	
CQUAD4	107	2	645	663	664	646		.0625	
CQUAD4	108	2	646	664	666	648		.0625	
CQUAD4	109	2	660	669	671	662		.0625	
CQUAD4	110	2	662	671	672	663		.0625	
CQUAD4	111	2	663	672	673	664		.0625	
CQUAD4	112	2	664	673	675	666		.0625	
CQUAD4	113	2	669	678	680	671		.0625	
CQUAD4	114	2	671	680	681	672		.0625	
CQUAD4	115	2	672	681	682	673		.0625	
CQUAD4	116	2	673	682	684	675		.0625	
CQUAD4	117	2	678	687	689	680		.0625	
CQUAD4	118	2	680	689	690	681		.0625	
CQUAD4	119	2	681	690	691	682		.0625	
CQUAD4	120	2	682	691	693	684		.0625	
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CQUAD4	123	2	690	699	700	691		.0625	
CQUAD4	124	2	691	700	702	693		.0625	
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CQUAD4	126	2	698	707	708	699		.0625	
CQUAD4	127	2	699	708	709	700		.0625	
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CQUAD4	129	2	705	714	716	707		.0625	
CQUAD4	130	2	707	716	717	708		.0625	
CQUAD4	131	2	708	717	718	709		.0625	
CQUAD4	132	2	709	718	720	711		.0625	
CQUAD4	133	2	714	723	725	716		.0625	
CQUAD4	134	2	716	725	726	717		.0625	
CQUAD4	135	2	717	726	727	718		.0625	
CQUAD4	136	2	718	727	729	720		.0625	
CQUAD4	137	2	723	732	734	725		.0625	
CQUAD4	138	2	725	734	735	726		.0625	
CQUAD4	139	2	726	735	736	727		.0625	
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CQUAD4	141	2	732	750	752	734		.0625	
CQUAD4	142	2	734	752	753	735		.0625	
CQUAD4	143	2	735	753	754	736		.0625	
CQUAD4	144	2	736	754	756	738		.0625	
CHEXA	145	3	92	101	102	93	1	8	E 145
+E 145	9	2							
CHEXA	146	3	93	102	104	95	2	9	E 146
+E 146	10	3							
CHEXA	147	3	95	104	105	96	3	10	E 147

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+E    147    11     4
CHEXA        148    3    96    105    106    97     4     11 E    148
+E    148    12     5
CHEXA        149    3    97    106    108    99     5     12 E    149
+E    149    13     6
CHEXA        150    3    99    108    109    100    6     13 E    150
+E    150    14     7
CHEXA        151    3    108   126    127    109    13    20 E    151
+E    151    21     14
CHEXA        152    3    126   135    136    127    20.   27 E    152
+E    152    28     21
CHEXA        153    3    135   144    145    136    27    34 E    153
+E    153    35     28
CHEXA        154    3    144   153    154    145    34    41 E    154
+E    154    42     35
CHEXA        155    3    153   162    163    154    41    48 E    155
+E    155    49     42
CHEXA        156    3    162   171    172    163    48    55 E    156
+E    156    56     49
CHEXA        157    3    171   180    181    172    55    62 E    157
+E    157    63     56
CHEXA        158    3    180   189    190    181    62    69 E    158
+E    158    70     63
CHEXA        159    3    189   198    199    190    69    76 E    159
+E    159    77     70
CHEXA        160    3    198   216    217    199    76    83 E    160
+E    160    84     77
CHEXA        161    3    216   225    226    217    83    90 E    161
+E    161    91     84
CHEXA        162    3    214   223    225    216    82    89 E    162
+E    162    90     83
CHEXA        163    3    213   222    223    214    81    88 E    163
+E    163    89     82
CHEXA        164    3    212   221    222    213    80    87 E    164
+E    164    88     81
CHEXA        165    3    210   219    221    212    79    86 E    165
+E    165    87     80
CHEXA        166    3    209   218    219    210    78    85 E    166
+E    166    86     79
CHEXA        167    3    191   209    210    192    71    78 E    167
+E    167    79     72
CHEXA        168    3    182   191    192    183    64    71 E    168
+E    168    72     65
CHEXA        169    3    173   182    183    174    57    64 E    169
+E    169    65     58
CHEXA        170    3    164   173    174    165    50    57 E    170
+E    170    58     51
CHEXA        171    3    155   164    165    156    43    50 E    171
+E    171    51     44
CHEXA        172    3    146   155    156    147    36    43 E    172
+E    172    44     37
CHEXA        173    3    137   146    147    138    29    36 E    173
+E    173    37     30
CHEXA        174    3    128   137    138    129    22    29 E    174
+E    174    30     23
CHEXA        175    3    119   128    129    120    15    22 E    175
+E    175    23     16
CHEXA        176    3    101   119    120    102    8     15 E    176
+E    176    16     9
CHEXA        177    6    112   121    122    113    9     16 E    177
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+E    177        17         10
CHEXA           178          6       113       122       123       114        10        17 E      178
+E    178        _8         11
CHEXA           179          6       114       123       124       115        11        18 E      179
+E    179        19         12
CHEXA           180          6       115       124       125       116        12        19 E      180
+E    180        20         13
CHEXA           181          6       121       130       131       122        16        23 E      181
+E    181        24         17
CHEXA           182          6       122       131       132       123        17        24 E      182
+E    182        25         18
CHEXA           183          6       123       132       133       124        18        25 E      183
+E    183        26         19
CHEXA           184          6       124       133       134       125        19        26 E      184
+E    184        27         20
CHEXA           185          6       130       139       140       131        23        30 E      185
+E    185        31         24
CHEXA           186          6       131       140       141       132        24        31 E      186
+E    186        32         25
CHEXA           187          6       132       141       142       133        25        32 E      187
+E    187        33         26
CHEXA           188          6       133       142       143       134        26        33 E      188
+E    188        34         27
CHEXA           189          6       139       148       149       140        30        37 E      189
+E    189        38         31
CHEXA           190          6       140       149       150       141        31        38 E      190
+E    190        39         32
CHEXA           191          6       141       150       151       142        32        39 E      191
+E    191        40         33
CHEXA           192          6       142       151       152       143        33        40 E      192
+E    192        41         34
CHEXA           193          6       148       157       158       149        37        44 E      193
+E    193        45         38
CHEXA           194          6       149       158       159       150        38        45 E      194
+E    194        46         39
CHEXA           195          6       150       159       160       151        39        46 E      195
+E    195        47         40
CHEXA           196          6       151       160       161       152        40        47 E      196
+E    196        48         41
CHEXA           197          6       157       166       167       158        44        51 E      197
+E    197        52         45
CHEXA           198          6       158       167       168       159        45        52 E      198
+E    198        53         46
CHEXA           199          6       159       168       169       160        46        53 E      199
+E    199        54         47
CHEXA           200          6       160       169       170       161        47        54 E      200
+E    200        55         48
CHEXA           201          6       166       175       176       167        51        58 E      201
+E    201        59         52
CHEXA           202          6       167       176       177       168        52        59 E      202
+E    202        60         53
CHEXA           203          6       168       177       17[illegible]  16[illegible]  53   60 E      203
+E    203        61         54
CHEXA           204          6       169       178       179       170        54        61 E      204
+E    204        62         55
CHEXA           205          6       175       184       185       176        58        65 E      205
+E    205        66         59
CHEXA           206          6       176       185       186       177        59        66 E      206
+E    206        67         60
CHEXA           207          6       177       186       187       178        60        67 E      207
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+E 207	68	61							
CHEXA	208	6	178	187	188	179	61	68 E	208
+E 208	69	62							
CHEXA	209	6	184	193	194	185	65	72 E	209
+E 209	73	66							
CHEXA	210	6	185	194	195	186	66	73 E	210
+E 210	74	67							
CHEXA	211	6	186	195	196	187	67	74 E	211
+E 211	75	68							
CHEXA	212	6	187	196	197	188	68	75 E	212
+E 212	76	69							
CHEXA	213	6	193	202	203	194	72	79 E	213
+E 213	80	73							
CHEXA	214	6	194	203	204	195	73	80 E	214
+E 214	81	74							
CHEXA	215	6	195	204	205	196	74	81 E	215
+E 215	82	75							
CHEXA	216	6	196	205	206	197	75	82 E	216
+E 216	83	76							
CHEXA	217	3	227	236	237	228	92	101 E	217
+E 217	102	93							
CHEXA	218	3	228	237	239	230	93	102 E	218
+E 218	104	95							
CHEXA	219	3	230	239	240	231	95	104 E	219
+E 219	105	96							
CHEXA	220	3	231	240	241	232	96	105 E	220
+E 220	106	97							
CHEXA	221	3	232	241	243	234	97	106 E	221
+E 221	108	99							
CHEXA	222	3	234	243	244	235	99	108 E	222
+E 222	109	100							
CHEXA	223	3	243	261	262	244	108	126 E	223
+E 223	127	109							
CHEXA	224	3	261	270	271	262	126	135 E	224
+E 224	136	127							
CHEXA	225	3	270	279	280	271	135	144 E	225
+E 225	145	136							
CHEXA	226	3	279	288	289	280	144	153 E	226
+E 226	154	145							
CHEXA	227	3	288	297	298	289	153	162 E	227
+E 227	163	154							
CHEXA	228	3	297	306	307	298	162	171 E	228
+E 228	172	163							
CHEXA	229	3	306	315	316	307	171	180 E	229
+E 229	181	172							
CHEXA	230	3	315	324	325	316	180	189 E	230
+E 230	190	181							
CHEXA	231	3	324	333	334	325	189	198 E	231
+E 231	199	190							
CHEXA	232	3	333	351	352	334	198	216 E	232
+E 232	217	199							
CHEXA	233	3	351	360	361	[illegible]	216	225 E	233
+E 233	226	217							
CHEXA	234	3	349	358	360	351	214	223 E	234
+E 234	225	216							
CHEXA	235	3	348	357	358	349	213	222 E	235
+E 235	223	214							
CHEXA	236	3	347	356	357	348	212	221 E	236
+E 236	222	213							
CHEXA	237	3	345	354	356	347	210	219 E	237

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+E     237      221      212
CHEXA           238        3      344      353      354      345      209      218 E     238
+E     238      219      210
CHEXA           239        3      326      344      345      327      191      209 E     239
+E     239      210      192
CHEXA           240        3      317      326      327      318      182      191 E     240
+E     240      192      183
CHEXA           241        3      308      317      318      309      173      182 E     241
+E     241      183      174
CHEXA           242        3      299      308      309      300      164      173 E     242
+E     242      174      165
CHEXA           243        3      290      299      300      291      155      164 E     243
+E     243      165      156
CHEXA           244        3      281      290      291      282      146      155 E     244
+E     244      156      147
CHEXA           245        3      272      281      282      273      137      146 E     245
+E     245      147      138
CHEXA           246        3      263      272      273      264      128      137 E     246
+E     246      138      129
CHEXA           247        3      254      263      264      255      119      128 E     247
+E     247      129      120
CHEXA           248        3      236      254      255      237      101      119 E     248
+E     248      120      102
CHEXA           249        4      247      256      257      248      112      121 E     249
+E     249      122      113
CHEXA           250        4      248      257      258      249      113      122 E     250
+E     250      123      114
CHEXA           251        4      249      258      259      250      114      123 E     251
+E     251      124      115
CHEXA           252        4      250      259      260      251      115      124 E     252
+E     252      125      116
CHEXA           253        4      256      265      266      257      121      130 E     253
+E     253      131      122
CHEXA           254        4      257      266      267      258      122      131 E     254
+E     254      132      123
CHEXA           255        4      258      267      268      259      123      132 E     255
+E     255      133      124
CHEXA           256        4      259      268      269      260      124      133 E     256
+E     256      134      125
CHEXA           257        4      265      274      275      266      130      139 E     257
+E     257      140      131
CHEXA           258        4      266      275      276      267      131      140 E     258
+E     258      141      132
CHEXA           259        4      267      276      277      268      132      141 E     259
+E     259      142      133
CHEXA           260        4      268      277      278      269      133      142 E     260
+E     260      143      134
CHEXA           261        4      274      283      284      275      139      148 E     261
+E     261      149      140
CHEXA           262        4      275      284      285      276      140      149 E     262
+E     262      150      141
CHEXA           263        4      276      285      286      277      141      150 E     263
+E     263      151      142
CHEXA           264        4      277      286      287      278      142      151 E     264
+E     264      152      143
CHEXA           265        4      283      292      293      284      148      157 E     265
+E     265      158      149
CHEXA           266        4      284      293      294      285      149      158 E     266
+E     266      159      150
CHEXA           267        4      285      294      295      286      150      159 E     267
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+E   267    160    151
CHEXA       268      4    286    295    296    287    151    160 E  268
+E   268    161    152
CHEXA       269      4    292    301    302    293    157    166 E  269
+E   269    167    158
CHEXA       270      4    293    302    303    294    158    167 E  270
+E   270    168    159
CHEXA       271      4    294    303    304    295    159    168 E  271
+E   271    169    160
CHEXA       272      4    295    304    305    296    160    169 E  272
+E   272    170    161
CHEXA       273      4    301    310    311    302    166    175 E  273
+E   273    176    167
CHEXA       274      4    302    311    312    303    167    176 E  274
+E   274    177    168
CHEXA       275      4    303    312    313    304    168    177 E  275
+E   275    178    169
CHEXA       276      4    304    313    314    305    169    178 E  276
+E   276    179    170
CHEXA       277      4    310    319    320    311    175    184 E  277
+E   277    185    176
CHEXA       278      4    311    320    321    312    176    185 E  278
+E   278    186    177
CHEXA       279      4    312    321    322    313    177    186 E  279
+E   279    187    178
CHEXA       280      4    313    322    323    314    178    187 E  280
+E   280    188    179
CHEXA       281      4    319    328    329    320    184    193 E  281
+E   281    194    185
CHEXA       282      4    320    329    330    321    185    194 E  282
+E   282    195    186
CHEXA       283      4    321    330    331    322    186    195 E  283
+E   283    196    187
CHEXA       284      4    322    331    332    323    187    196 E  284
+E   284    197    188
CHEXA       285      4    328    337    338    329    193    202 E  285
+E   285    203    194
CHEXA       286      4    329    338    339    330    194    203 E  286
+E   286    204    195
CHEXA       287      4    330    339    340    331    195    204 E  287
+E   287    205    196
CHEXA       288      4    331    340    341    332    196    205 E  288
+E   288    206    197
CHEXA       289      3    362    371    372    363    227    236 E  289
+E   289    237    228
CHEXA       290      3    363    372    374    365    228    237 E  290
+E   290    239    230
CHEXA       291      3    365    374    375    366    230    239 E  291
+E   291    240    231
CHEXA       292      3    366    375    376    367    231    240 E  292
+E   292    241    232
CHEXA       293      3    367    376    378    369    232    241 E  293
+E   293    243    234
CHEXA       294      3    369    378    379    370    234    243 E  294
+E   294    244    235
CHEXA       295      3    378    396    397    379    243    261 E  295
+E   295    262    244
CHEXA       296      3    396    405    406    397    261    270 E  296
+E   296    271    262
CHEXA       297      3    405    414    415    406    270    279 E  297
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+E   297      280         271
CHEXA         298           3      414      423      424      415      279      288 E    298
+E   298      289         280
CHEXA         299           3      423      432      433      424      288      297 E    299
+E   299      298         289
CHEXA         300           3      432      441      442      433      297      306 E    300
+E   300      307         298
CHEXA         301           3      441      450      451      442      306      315 E    301
+E   301      316         307
CHEXA         302           3      450      459      460      451      315      324 E    302
+E   302      325         316
CHEXA         303           3      459      468      469      460      324      333 E    303
+E   303      334         325
CHEXA         304           3      468      486      487      469      333      351 E    304
+E   304      352         334
CHEXA         305           3      486      495      496      487      351      360 E    305
+E   305      361         352
CHEXA         306           3      484      493      495      486      349      358 E    306
+E   306      360         351
CHEXA         307           3      483      492      493      484      348      357 E    307
+E   307      358         349
CHEXA         308           3      482      491      492      483      347      356 E    308
+E   308      357         348
CHEXA         309           3      480      489      491      482      345      354 E    309
+E   309      356         347
CHEXA         310           3      479      488      489      480      344      353 E    310
+E   310      354         345
CHEXA         311           3      461      479      480      462      326      344 E    311
+E   311      345         327
CHEXA         312           3      452      461      462      453      317      326 E    312
+E   312      327         318
CHEXA         313           3      443      452      453      444      308      317 E    313
+E   313      318         309
CHEXA         314           3      434      443      444      435      299      308 E    314
+E   314      309         300
CHEXA         315           3      425      434      435      426      290      299 E    315
+E   315      300         291
CHEXA         316           3      416      425      426      417      281      290 E    316
+E   316      291         282
CHEXA         317           3      407      416      417      408      272      281 E    317
+E   317      282         273
CHEXA         318           3      398      407      408      399      263      272 E    318
+E   318      273         264
CHEXA         319           3      389      398      399      390      254      263 E    319
+E   319      264         255
CHEXA         320           3      371      389      390      372      236      254 E    320
+E   320      255         237
CHEXA         321           4      382      391      392      383      247      256 E    321
+E   321      257         248
CHEXA         322           4      383      392      393      384      248      257 E    322
+E   322      258         249
CHEXA         323           4      384      393      394      385      249      258 E    323
+E   323      259         250
CHEXA         324           4      385      394      395      386      250      259 E    324
+E   324      260         251
CHEXA         325           4      391      400      401      392      256      265 E    325
+E   325      266         257
CHEXA         326           4      392      401      402      393      257      266 E    326
+E   326      267         258
CHEXA         327           4      393      402      403      394      258      267 E    327
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+E 327	268	259								
CHEXA	328	4	394	403	404	395	259	268	E	328
+E 328	269	260								
CHEXA	329	4	400	409	410	401	265	274	E	329
+E 329	275	266								
CHEXA	330	4	401	410	411	402	266	275	E	330
+E 330	276	267								
CHEXA	331	4	402	411	412	403	267	276	E	331
+E 331	277	268								
CHEXA	332	4	403	412	413	404	268	277	E	332
+E 332	278	269								
CHEXA	333	4	409	418	419	410	274	283	E	333
+E 333	284	275								
CHEXA	334	4	410	419	420	411	275	284	E	334
+E 334	285	276								
CHEXA	335	4	411	420	421	412	276	285	E	335
+E 335	286	277								
CHEXA	336	4	412	421	422	413	277	286	E	336
+E 336	287	278								
CHEXA	337	4	418	427	428	419	283	292	E	337
+E 337	293	284								
CHEXA	338	4	419	428	429	420	284	293	E	338
+E 338	294	285								
CHEXA	339	4	420	429	430	421	285	294	E	339
+E 339	295	286								
CHEXA	340	4	421	430	431	422	286	295	E	340
+E 340	296	287								
CHEXA	[illegible]	4	427	436	437	428	292	301	E	341
+E 341	302	293								
CHEXA	342	4	428	437	438	429	293	302	E	342
+E 342	303	294								
CHEXA	343	4	429	438	439	430	294	303	E	343
+E 343	304	295								
CHEXA	344	4	430	439	440	431	295	304	E	344
+E 344	305	296								
CHEXA	345	4	436	445	446	437	301	310	E	345
+E 345	311	302								
CHEXA	346	4	437	446	447	438	302	311	E	346
+E 346	312	303								
CHEXA	347	4	438	447	448	439	303	312	E	347
+E 347	313	304								
CHEXA	348	4	439	448	449	440	304	313	E	348
+E 348	314	305								
CHEXA	349	4	445	454	455	446	310	319	E	349
+E 349	320	311								
CHEXA	350	4	446	455	456	447	311	320	E	350
+E 350	321	312								
CHEXA	351	4	447	456	457	448	312	321	E	351
+E 351	322	313								
CHEXA	352	4	448	457	458	449	313	322	E	352
+E 352	323	314								
CHEXA	353	4	454	463	464	[illegible]	319	328	E	353
+E 353	329	320								
CHEXA	354	4	455	464	465	456	320	329	E	354
+E 354	330	321								
CHEXA	355	4	456	465	466	457	321	330	E	355
+E 355	331	322								
CHEXA	356	4	457	466	467	458	322	331	E	356
+E 356	332	323								
CHEXA	357	4	463	472	473	464	328	337	E	357

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+E     357        338        329
CHEXA             358          4     464     473     474     465     329     338 E     358
+E     358        339        330
CHEXA             359          4     465     474     475     466     330     339 E     359
+E     359        340        331
CHEXA             360          4     466     475     476     467     331     340 E     360
+E     360        341        332
CHEXA             361          3     497     506     507     498     362     371 E     361
+E     361        372        363
CHEXA             362          3     498     507     509     500     363     372 E     362
+E     362        374        365
CHEXA             363          3     500     509     510     501     365     374 E     363
+E     363        375        366
CHEXA             364          3     501     510     511     502     366     375 E     364
+E     364        376        367
CHEXA             365          3     502     511     513     504     367     376 E     365
+E     365        378        369
CHEXA             366          3     504     513     514     505     369     378 E     366
+E     366        379        370
CHEXA             367          3     513     531     532     514     378     396 E     367
+E     367        397        379
CHEXA             368          3     531     540     541     532     396     405 E     368
+E     368        406        397
CHEXA             369          3     540     549     550     541     405     414 E     369
+E     369        415        406
CHEXA             370          3     549     558     559     550     414     423 E     370
+E     370        424        415
CHEXA             371          3     558     567     568     559     423     432 E     371
+E     371        433        424
CHEXA             372          3     567     576     577     568     432     441 E     372
+E     372        442        433
CHEXA             373          3     576     585     586     577     441     450 E     373
+E     373        451        442
CHEXA             374          3     585     594     595     586     450     459 E     374
+E     374        460        451
CHEXA             375          3     594     603     604     595     459     468 E     375
+E     375        469        460
CHEXA             376          3     603     621     622     604     468     486 E     376
+E     376        487        469
CHEXA             377          3     621     630     631     622     486     495 E     377
+E     377        496        487
CHEXA             378          3     619     628     630     621     484     493 E     378
+E     378        495        486
CHEXA             379          3     618     627     628     619     483     492 E     379
+E     379        493        484
CHEXA             380          3     617     626     627     618     482     491 E     380
+E     380        492        483
CHEXA             381          3     615     624     626     617     480     489 E     381
+E     381        491        482
CHEXA             382          3     614     623     624     615     479     488 E     382
+E     382        489        480
CHEXA             383          3     596     614     615     597     461     470 E     383
+E     383        480        462
CHEXA             384          3     587     596     597     588     452     461 E     384
+E     384        462        453
CHEXA             385          3     578     587     588     579     443     452 E     385
+E     385        453        444
CHEXA             386          3     569     578     579     570     434     443 E     386
+E     386        444        435
CHEXA             387          3     560     569     570     561     425     434 E     387
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+E    387       435      426
CHEXA           388        3     551     560     561     552     416     425 E   388
+E    388       426      417
CHEXA           389        3     542     551     552     543     407     416 E   389
+E    389       417      408
CHEXA           390        3     533     542     543     534     398     407 E   390
+E    390       408      399
CHEXA           391        3     524     533     534     525     389     398 E   391
+E    391       399      390
CHEXA           392        3     506     524     525     507     371     389 E   392
+E    392       390      372
CHEXA           393        4     517     526     527     518     382     391 E   393
+E    393       392      383
CHEXA           394        4     518     527     528     519     383     392 E   394
+E    394       393      384
CHEXA           395        4     519     528     529     520     384     393 E   395
+E    395       394      385
CHEXA           396        4     520     529     530     521     385     394 E   396
+E    396       395      386
CHEXA           397        4     526     535     536     527     391     400 E   397
+E    397       401      392
CHEXA           398        4     527     536     537     528     392     401 E   398
+E    398       402      393
CHEXA           399        4     528     537     538     529     393     402 E   399
+E    399       403      394
CHEXA           400        4     529     538     539     530     394     403 E   400
+E    400       404      395
CHEXA           401        4     535     544     545     536     400     409 E   401
+E    401       410      401
CHEXA           402        4     536     545     546     537     401     410 E   402
+E    402       411      402
CHEXA           403        4     537     546     547     538     402     411 E   403
+E    403       412      403
CHEXA           404        4     538     547     548     539     403     412 E   404
+E    404       413      404
CHEXA           405        4     544     553     554     545     409     418 E   405
+E    405       419      410
CHEXA           406        4     545     554     555     546     410     419 E   406
+E    406       420      411
CHEXA           407        4     546     555     556     547     411     420 E   407
+E    407       421      412
CHEXA           408        4     547     556     557     548     412     421 E   408
+E    408       422      413
CHEXA           409        4     553     562     563     554     418     427 E   409
+E    409       428      419
CHEXA           410        4     554     563     564     555     419     428 E   410
+E    410       429      420
CHEXA           411        4     555     564     565     556     420     429 E   411
+E    411       430      421
CHEXA           412        4     556     565     566     557     421     430 E   412
+E    412       431      422
CHEXA           413        4     562     571     572     563     427     436 E   413
+E    413       437      428
CHEXA           414        4     563     572     573     564     428     437 E   414
+E    414       438      429
CHEXA           415        4     564     573     574     565     429     438 E   415
+E    415       439      430
CHEXA           416        4     565     574     575     566     430     439 E   416
+E    416       440      431
CHEXA           417        4     571     580     581     572     436     445 E   417
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+E    417       446       437
CHEXA           418         4       572       581       582       573       437       446 E     418
+E    418       447       438
CHEXA           419         4       573       582       583       574       438       447 E     419
+E    419       448       439
CHEXA           420         4       574       583       584       575       439       448 E     420
+E    420       449       440
CHEXA           421         4       580       589       590       581       445       454 E     421
+E    421       455       446
CHEXA           422         4       581       590       591       582       446       455 E     422
+E    422       456       447
CHEXA           423         4       582       591       592       583       447       456 E     423
+E    423       457       448
CHEXA           424         4       583       592       593       584       448       457 E     424
+E    424       458       449
CHEXA           425         4       589       598       599       590       454       463 E     425
+E    425       464       455
CHEXA           426         4       590       599       600       591       455       464 E     426
+E    426       465       456
CHEXA           427         4       591       600       601       592       456       465 E     427
+E    427       466       457
CHEXA           428         4       592       601       602       593       457       466 E     428
+E    428       467       458
CHEXA           429         4       598       607       608       599       463       472 E     429
+E    429       473       464
CHEXA           430         4       599       608       609       600       464       473 E     430
+E    430       474       465
CHEXA           431         4       600       609       610       601       465       474 E     431
+E    431       475       466
CHEXA           432         4       601       610       611       602       466       475 E     432
+E    432       476       467
CHEXA           433         3       632       641       642       633       497       506 E     433
+E    433       507       498
CHEXA           434         3       633       642       644       635       498       507 E     434
+E    434       509       500
CHEXA           435         3       635       644       645       636       500       509 E     435
+E    435       510       501
CHEXA           436         3       636       645       646       637       501       510 E     436
+E    436       511       502
CHEXA           437         3       637       646       648       639       502       511 E     437
+E    437       513       504
CHEXA           438         3       639       648       649       640       504       513 E     438
+E    438       514       505
CHEXA           439         3       648       666       667       649       513       531 E     439
+E    439       532       514
CHEXA           440         3       666       675       676       667       531       540 E     440
+E    440       541       532
CHEXA           441         3       675       684       685       676       540       549 E     441
+E    441       550       541
CHEXA           442         3       684       693       694       685       549       558 E     442
+E    442       559       550
CHEXA           443         3       693       702       703       694       558       567 E     443
+E    443       568       559
CHEXA           444         3       702       711       712       703       567       576 E     444
+E    444       577       568
CHEXA           445         3       711       720       721       712       576       585 E     445
+E    445       586       577
CHEXA           446         3       720       729       730       721       585       594 E     446
+E    446       595       586
CHEXA           447         3       729       738       739       730       594       603 E     447
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+E 447	604	595								
CHEXA	448	3	738	756	757	739	603	621	E	448
+E 448	622	604								
CHEXA	449	3	756	765	766	757	621	630	E	449
+E 449	631	622								
CHEXA	450	3	754	763	765	756	619	628	E	450
+E 450	630	621								
CHEXA	451	3	753	762	763	754	618	627	E	451
+E 451	628	619								
CHEXA	452	3	752	761	762	753	617	626	E	452
+E 452	627	618								
CHEXA	453	3	750	759	761	752	615	624	E	453
+E 453	626	617								
CHEXA	454	3	749	758	759	750	614	623	E	454
+E 454	624	615								
CHEXA	455	3	731	749	750	732	596	614	E	455
+E 455	615	597								
CHEXA	456	3	722	731	732	723	587	596	E	456
+E 456	597	588								
CHEXA	457	3	713	722	723	714	578	587	E	457
+E 457	588	579								
CHEXA	458	3	704	713	714	705	569	578	E	458
+E 458	579	570								
CHEXA	459	3	695	704	705	696	560	569	E	459
+E 459	570	561								
CHEXA	460	3	686	695	696	687	551	560	E	460
+E 460	561	552								
CHEXA	461	3	677	686	687	678	542	551	E	461
+E 461	552	543								
CHEXA	462	3	668	677	678	669	533	542	E	462
+E 462	543	534								
CHEXA	463	3	659	668	669	660	524	533	E	463
+E 463	534	525								
CHEXA	464	3	641	659	660	642	506	524	E	464
+E 464	525	507								
CHEXA	465	6	642	660	662	644	517	526	E	465
+E 465	527	518								
CHEXA	466	6	644	662	663	645	518	527	E	466
+E 466	528	519								
CHEXA	467	6	645	663	664	646	519	528	E	467
+E 467	529	520								
CHEXA	468	6	646	664	666	648	520	529	E	468
+E 468	530	521								
CHEXA	469	6	660	669	671	662	526	535	E	469
+E 469	536	527								
CHEXA	470	6	662	671	672	663	527	536	E	470
+E 470	537	528								
CHEXA	471	6	663	672	673	664	528	537	E	471
+E 471	538	529								
CHEXA	472	6	664	673	675	666	529	538	E	472
+E 472	539	530								
CHEXA	473	6	669	678	680	671	535	544	E	473
+E 473	545	536								
CHEXA	474	6	671	680	681	672	536	545	E	474
+E 474	546	537								
CHEXA	475	6	672	681	682	673	537	546	E	475
+E 475	547	538								
CHEXA	476	6	673	682	684	675	538	547	E	476
+E 476	548	539								
CHEXA	477	6	678	687	689	680	544	553	E	477

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+E     477      554      545
CHEXA           478      6       680      689      690      681      545      554 E    478
+E     478      555      546
CHEXA           479      6       681      690      691      682      546      555 E    479
+E     479      556      547
CHEXA           480      6       682      691      693      684      547      556 E    480
+E     480      557      548
CHEXA           481      6       687      696      698      689      553      562 E    481
+E     481      563      554
CHEXA           482      6       689      698      699      690      554      563 E    482
+E     482      564      555
CHEXA           483      6       690      699      700      691      555      564 E    483
+E     483      565      556
CHEXA           484      6       691      700      702      693      556      565 E    484
+E     484      566      557
CHEXA           485      6       696      705      707      698      562      571 E    485
+E     485      572      563
CHEXA           486      6       698      707      708      699      563      572 E    486
+E     486      573      564
CHEXA           487      6       699      708      709      700      564      573 E    487
+E     487      574      565
CHEXA           488      6       700      709      711      702      565      574 E    488
+E     488      575      566
CHEXA           489      6       705      714      716      707      571      580 E    489
+E     489      581      572
CHEXA           490      6       707      716      717      708      572      581 E    490
+E     490      582      573
CHEXA           491      6       708      717      718      709      573      582 E    491
+E     491      583      574
CHEXA           492      6       709      718      720      711      574      583 E    492
+E     492      584      575
CHEXA           493      6       714      723      725      716      580      589 E    493
+E     493      590      581
CHEXA           494      6       716      725      726      717      581      590 E    494
+E     494      591      582
CHEXA           495      6       717      726      727      718      582      591 E    495
+E     495      592      583
CHEXA           496      6       718      727      729      720      583      592 E    496
+E     496      593      584
CHEXA           497      6       723      732      734      725      589      598 E    497
+E     497      599      590
CHEXA           498      6       725      734      735      726      590      599 E    498
+E     498      600      591
CHEXA           499      6       726      735      736      727      591      600 E    499
+E     499      601      592
CHEXA           500      6       727      736      738      729      592      601 E    500
+E     500      602      593
CHEXA           501      6       732      750      752      734      598      607 E    501
+E     501      608      599
CHEXA           502      6       734      752      753      735      599      608 E    502
+E     502      609      600
CHEXA           503      6       735      753      754      736      600      609 E    503
+E     503      610      601
CHEXA           504      6       736      754      756      738      601      610 E    504
+E     504      611      602
PSHELL            1        1 0.47000         1 1.12200         1
PSHELL            2        1 0.12500         1 1.12200         1
PSOLID            3        3
PSOLID            4        1
PSOLID            5        1
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```
PSOLID          6        2
mat1,1,1.0e7,,0.33,2.58e-4
mat1,2,,573.934,0.49,9.067e-5
mat1,3,1.0e7,,0.33,2.58e-4
eigr,1,sinv,0.0,2000.0,,30,,,+eigr
+eigr,mass
suport,46,12345
spc1,1,6,1,thru,766
param,autospc,yes
param,asing,1
rload1,10,2001,,,3001
darea,2001,79,3,1.0
tabled1,3001,,,,,,,,+tal
+tal,0.0,1.0,5000.0,1.0,endt
freq1,10,5.0,1.0,1000
tabdmp1,101,,,,,,,,+dmp
+dmp,40.0,0.03487,70.64,0.042,121.32,0.0529,180.0,0.0643,+dmp1
+dmp1,245.0,0.075,320.0,0.0855,385.0,0.0926,490.0,0.1,+dmp2
+dmp2,535.0,0.1022,540.0,0.1023,570.0,0.1031,645.0,0.1033,+dmp3
+dmp3,695.0,0.102,725.0,0.101,775.0,0.098,895.0,0.087,+dmp4
+dmp4,940.0,0.0812,945.0,0.0805,1000.0,0.0723,endt
ENDDATA
```

LIST OF REFERENCES

1. Johnson, C.D. and Kienholz, D.A., "Finite Element Predition of Damping in Structures With Constrained Viscoelastic Layers," AIAA Journal, Vol. 20, No. 9, September 1982.

2. Bateman M.J., Constrained Viscoelastic Layer Damping of Thick Aluminum Plates: Design, Analysis and Testing, M.S. ,Thesis, U.S. Naval Posgraduate School, Monterey, California, March, 1990.

3. Maurer, G.J., Vibration Response of Constrained Viscoelastically Damped Plates; Analysis and Experiments, M.S. Thesis, U.S. Naval Postgraduate School, Monterey, California, December 1987.

4. Johnson, C.D. and Kienholz, D.A., "Finite Element Design of Viscoelastically Damped Structures," CSA Engineering, Inc., Palo Alto, California 1984.

5. MacNeal-Schwendler Corporation, MSC/NASTRAN Users Manual, Vol. 1, MacNeal-Schwendler Corporation, November, 1985.

6. Henderson, J.P., and Jones, D.I.G., "Fundamentals of Layered Damping Treatments,"Vibration Damping Short Course Notes, Section 6.1, University of Dayton, Dayton, Ohio, June 1987.

7. Johnson, C.D., and Kienholz, D.A., "Finite Element Prediction of Damping in Structures With Constrained Viscoelastic Layers," Report No. 82.053, Anamet Laboratiories, May 1982.

8. MacNeal-Schwendler Corporation, MSC/NASTRAN Handbook for Dynamic Analysis, Section 3.2.3, MacNeal-Schwendler Corporation, 1983.

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